US011733698B2

(12) **United States Patent**
Hanson et al.

(10) **Patent No.: US 11,733,698 B2**
(45) **Date of Patent: Aug. 22, 2023**

(54) **SYSTEMS AND METHODS FOR AUTONOMOUS SELECTION AND OPERATION OF COMBINATIONS OF STEALTH AND PERFORMANCE CAPABILITIES OF A MULTI-MODE UNMANNED VEHICLE**

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(72) Inventors: **Bruce Hanson**, Melbourne, FL (US); **Thomas Hanson**, Ashland, MA (US)

(73) Assignee: **UNMANNED INNOVATIONS, INC.**, Melbourne, FL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **18/051,057**

(22) Filed: **Oct. 31, 2022**

(65) **Prior Publication Data**

US 2023/0081946 A1 Mar. 16, 2023

Related U.S. Application Data

(63) Continuation of application No. 17/164,129, filed on Feb. 1, 2021, now Pat. No. 11,507,094, which is a (Continued)

(51) **Int. Cl.**
G05D 1/00 (2006.01)
B63B 1/04 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G05D 1/0088*** (2013.01); ***B63B 1/042*** (2013.01); *B63B 1/322* (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC G05D 1/0088; B63B 1/042; B63B 1/322; B63B 2001/206; B63B 2035/007;
(Continued)

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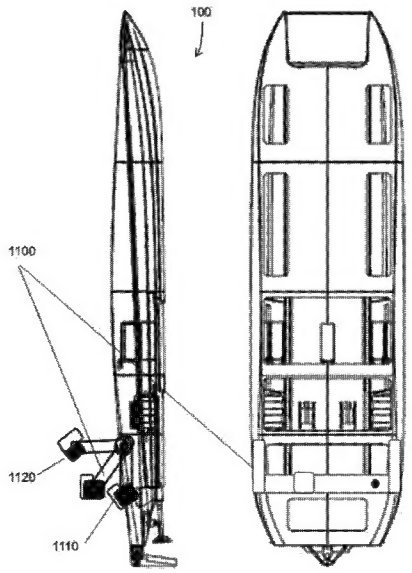
(Continued)

Primary Examiner — Isaac G Smith
(74) *Attorney, Agent, or Firm* — Mark Malek; Widerman Malek, PL

(57) **ABSTRACT**

An unmanned vehicle including a vehicle body, propulsion system, maneuvering system, vehicle control system, rack, sensor, and a power supply. The vehicle control may be used to control the unmanned vehicle in combination with the propulsion and the maneuvering system. The rack may include a retractable mount that may move between a down position and an up position. The sensor system may include a plurality of transient object detection sensors. The plurality of transient object detection sensors may include a sensor adapted to detect an item of interest and may provide an item of interest signal to the vehicle control system. The vehicle control system may identify an item of interest classification and may provide a classification signal. The classification signal may be determined by the item of interest classification and may be utilized to avoid detection of the unmanned vehicle by the item of interest.

16 Claims, 51 Drawing Sheets



Related U.S. Application Data

continuation-in-part of application No. 16/449,824, filed on Jun. 24, 2019, now Pat. No. 10,908,611, which is a continuation-in-part of application No. 15/609,459, filed on May 31, 2017, now Pat. No. 10,331,131, which is a continuation-in-part of application No. 14/788,231, filed on Jun. 30, 2015, now Pat. No. 9,669,904, which is a continuation-in-part of application No. 13/470,866, filed on May 14, 2012, now Pat. No. 9,096,106.

(51) **Int. Cl.**

B63B 1/32	(2006.01)
B63G 8/22	(2006.01)
B63B 1/20	(2006.01)
B63B 35/00	(2020.01)
B64C 3/38	(2006.01)

(52) **U.S. Cl.**

CPC ... *B63B 2001/206* (2013.01); *B63B 2035/007* (2013.01); *B63B 2035/008* (2013.01); *B63G 8/22* (2013.01); *B64C 3/38* (2013.01); *B64U 2201/20* (2023.01)

(58) **Field of Classification Search**

CPC B63B 2035/008; B63G 8/22; B64C 3/38; B64U 2201/20

USPC 701/23

See application file for complete search history.

(56) **References Cited**

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U.S. Appl. No. 15/609,459, filed May 31, 2017, now U.S. Pat. No. 10,331,131 issued Jun. 25, 2019.

U.S. Appl. No. 14/788,231, filed Jun. 30, 2015, now U.S. Pat. No. 9,669,904 issued Jun. 6, 2017.

U.S. Appl. No. 13/470,866, filed May 14, 2012, now U.S. Pat. No. 9,096,106 issued Aug. 4, 2015.

* cited by examiner

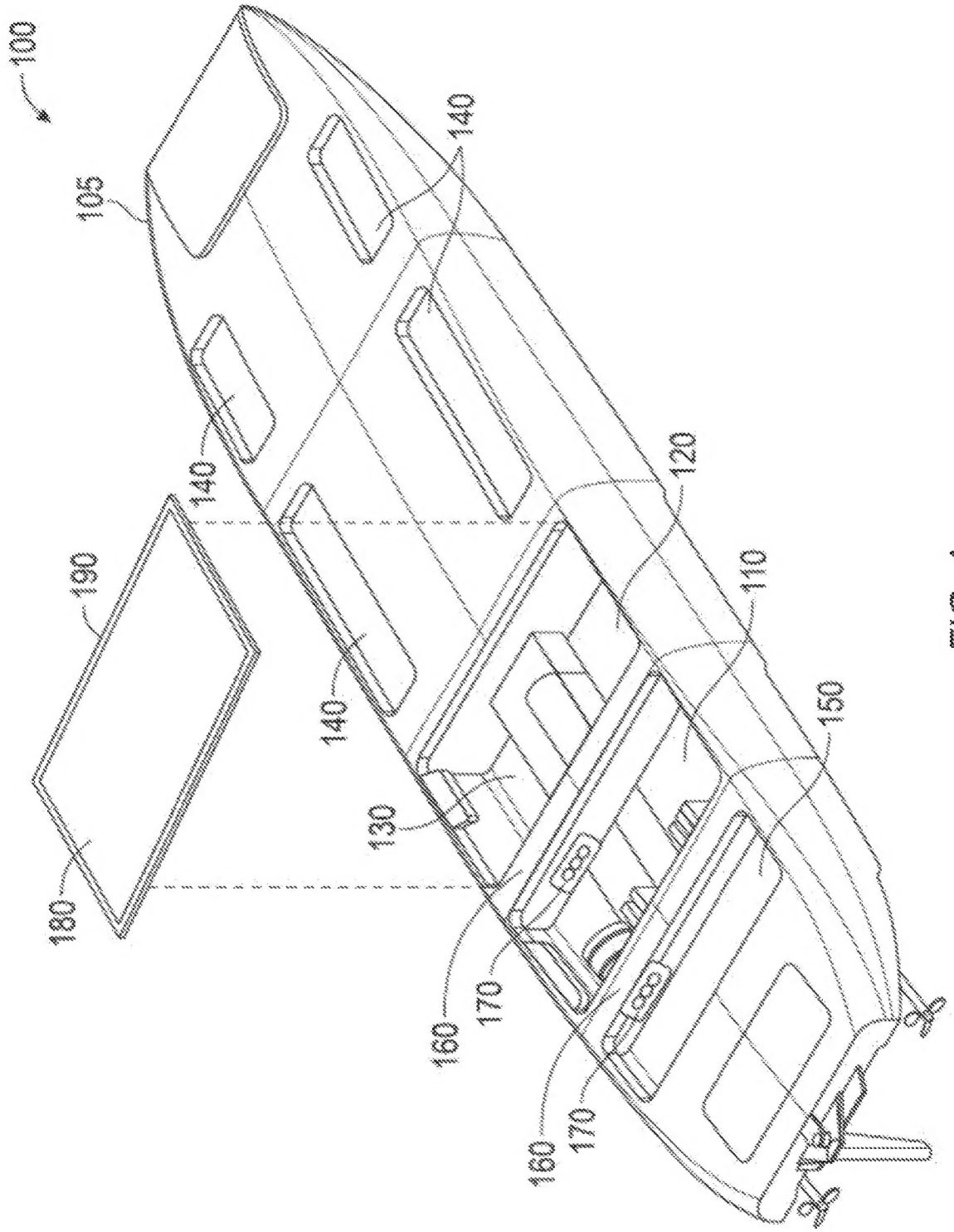

FIG. 1

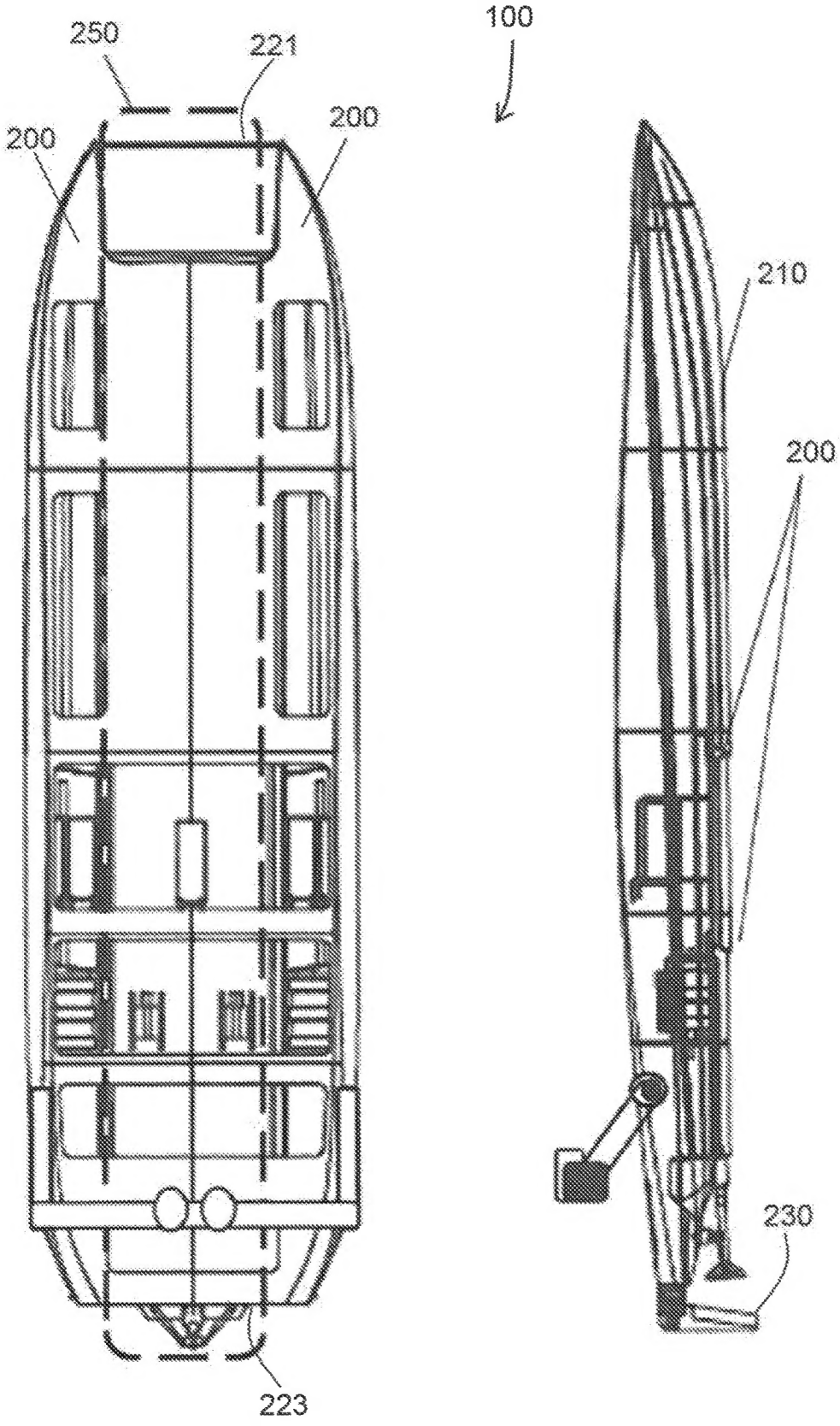

FIG. 2

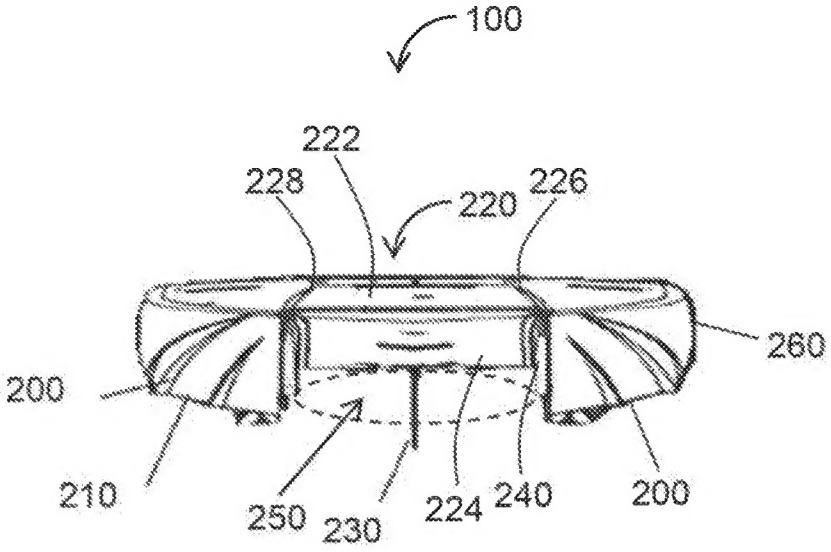

FIG. 2A

300

310 Vehicle	320 L/D (Lift to Drag Ratio)	330 Weight per Wing Area (lbs. / sq. foot)	340 Landing speed (Knots)	350 Minimum Air Speed (Knots)
Unmanned Vehicle	4.7	13	135*	65
Space Shuttle	4.5	32	220	85
Concorde	4.35	27	180	125

*Horizontal landing

FIG. 3

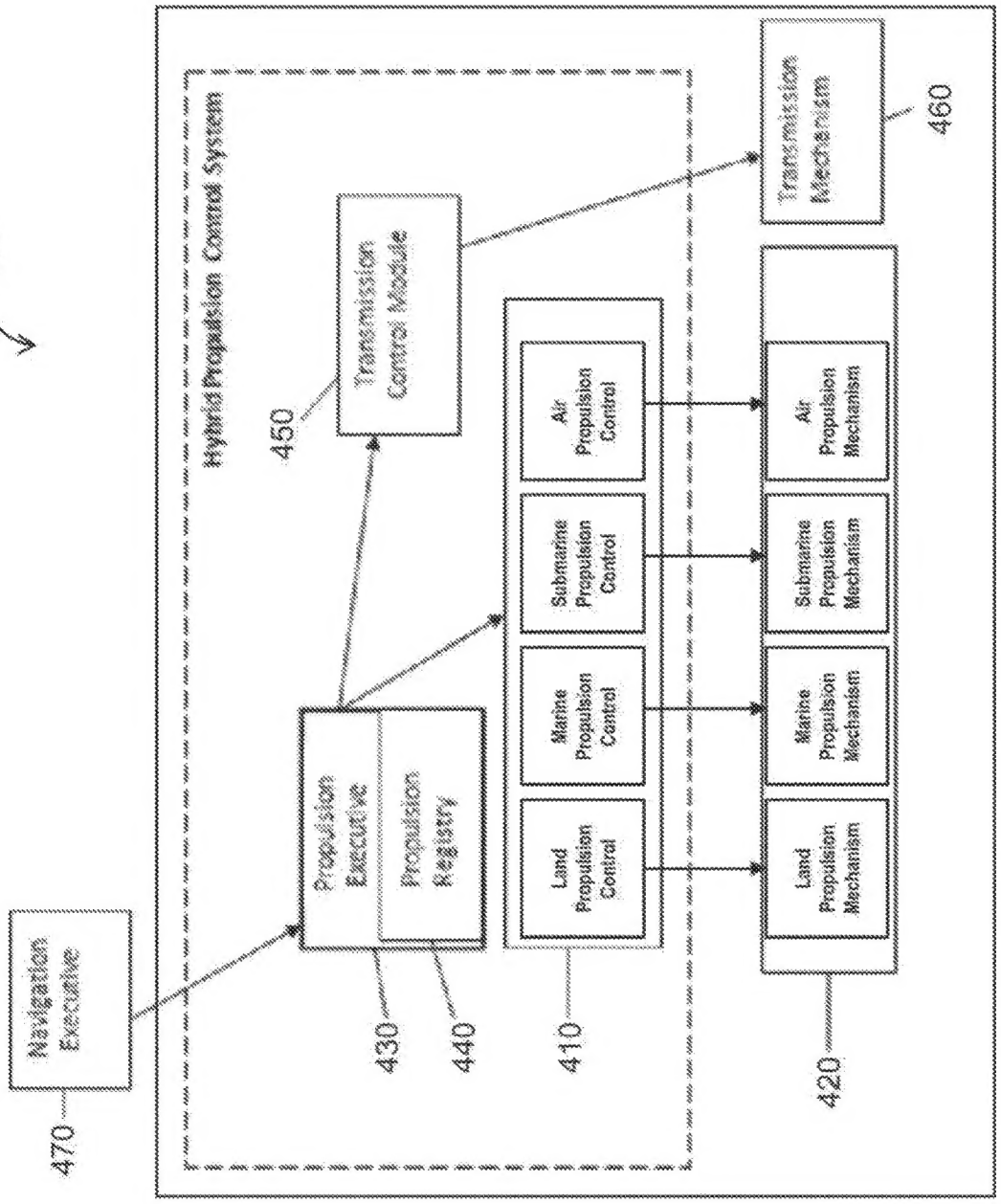
400
Hybrid Propulsion Control System
Navigation Executive
470
Propulsion Executive
Propulsion Registry
430
440
450
Transmission Control Module
Land Propulsion Control
Marine Propulsion Control
Submarine Propulsion Control
Air Propulsion Control
410
Land Propulsion Mechanism
Marine Propulsion Mechanism
Submarine Propulsion Mechanism
Air Propulsion Mechanism
420
Transmission Mechanism
460

FIG. 4

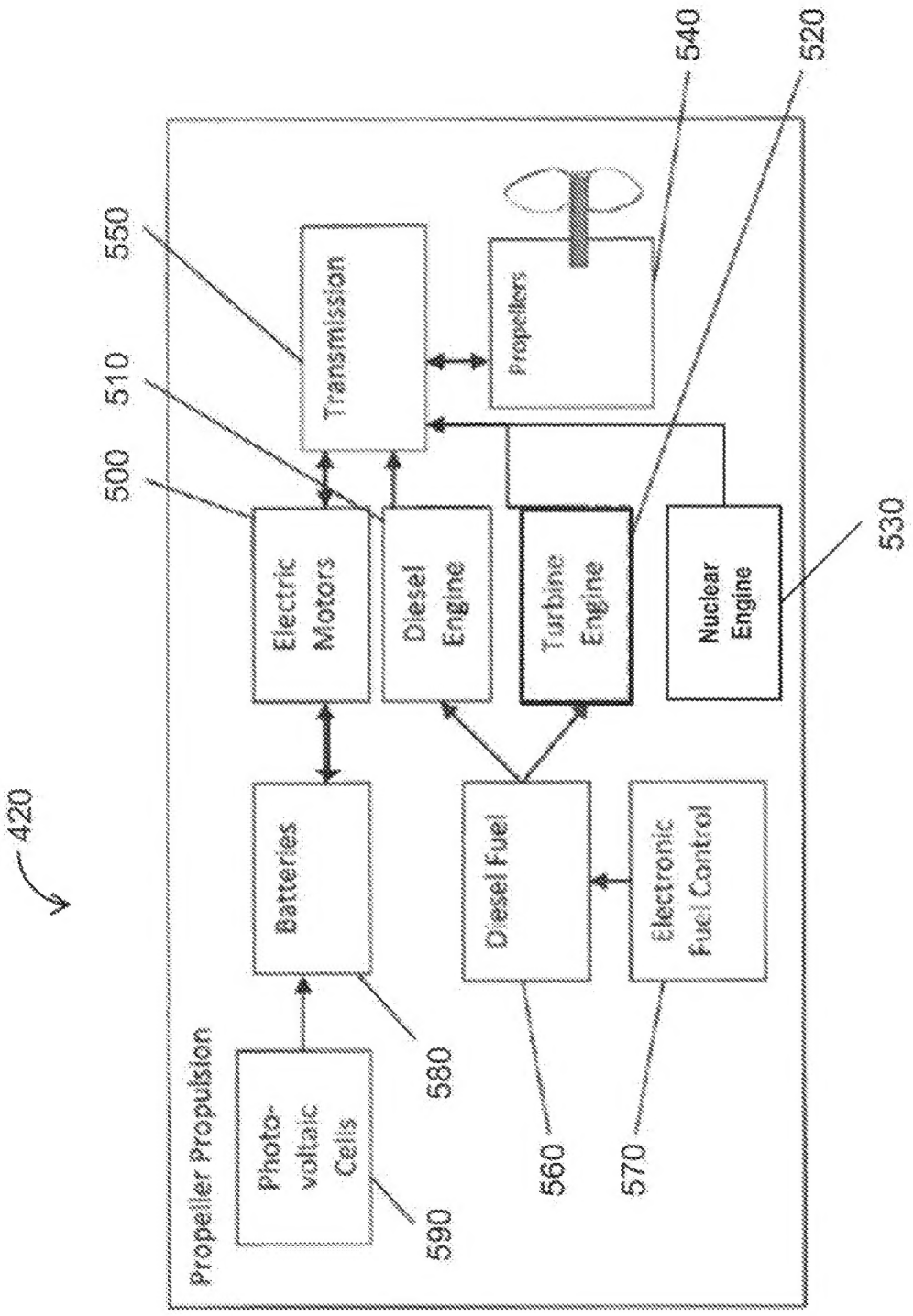
420
Propeller Propulsion
Photo-voltaic Cells
590
Batteries
580
Electric Motors
500
Diesel Engine
510
Transmission
550
Diesel Fuel
560
Electronic Fuel Control
570
Turbine Engine
Nuclear Engine
530
Propellers
540
520

FIG. 5

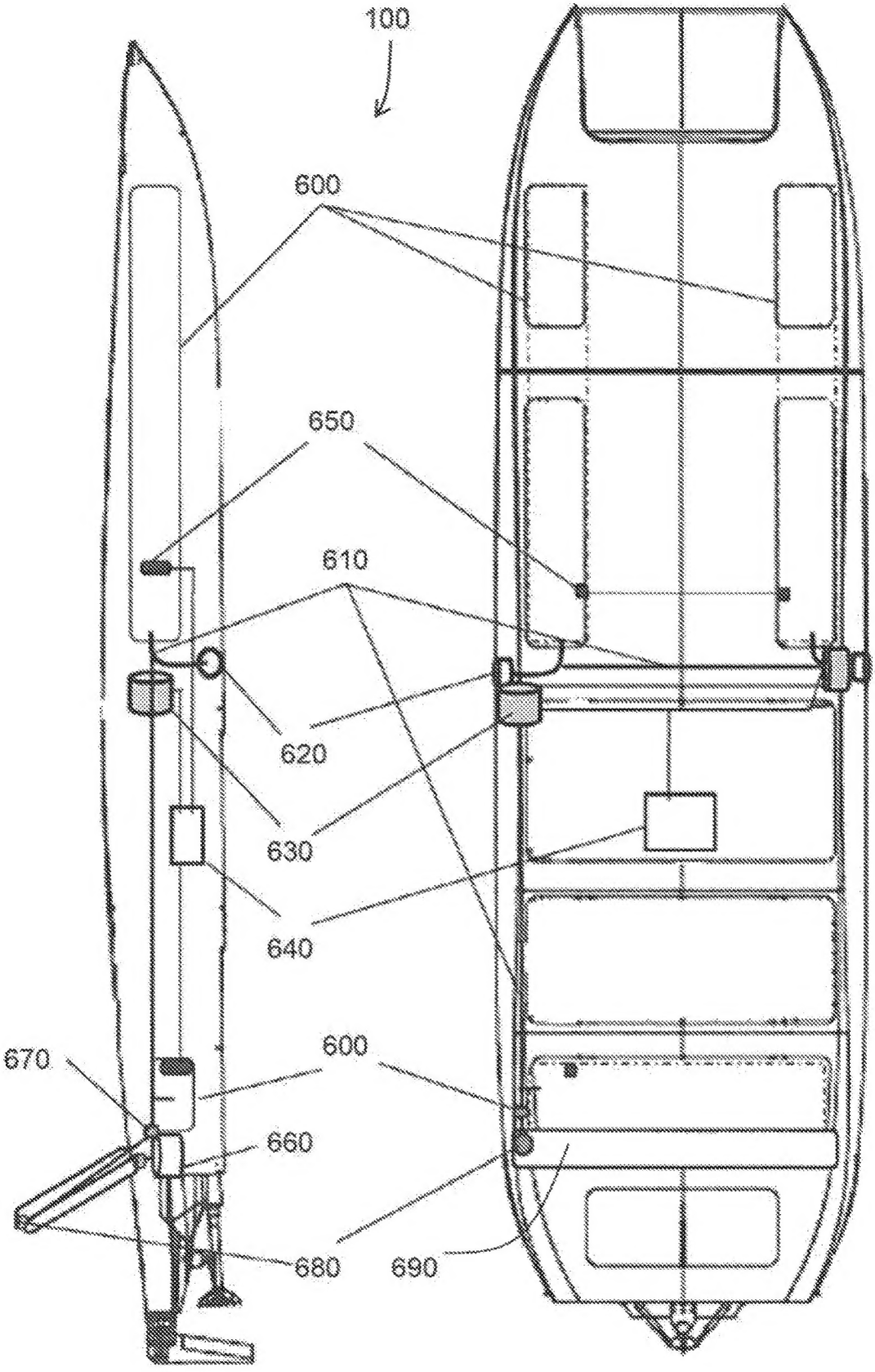

FIG. 6

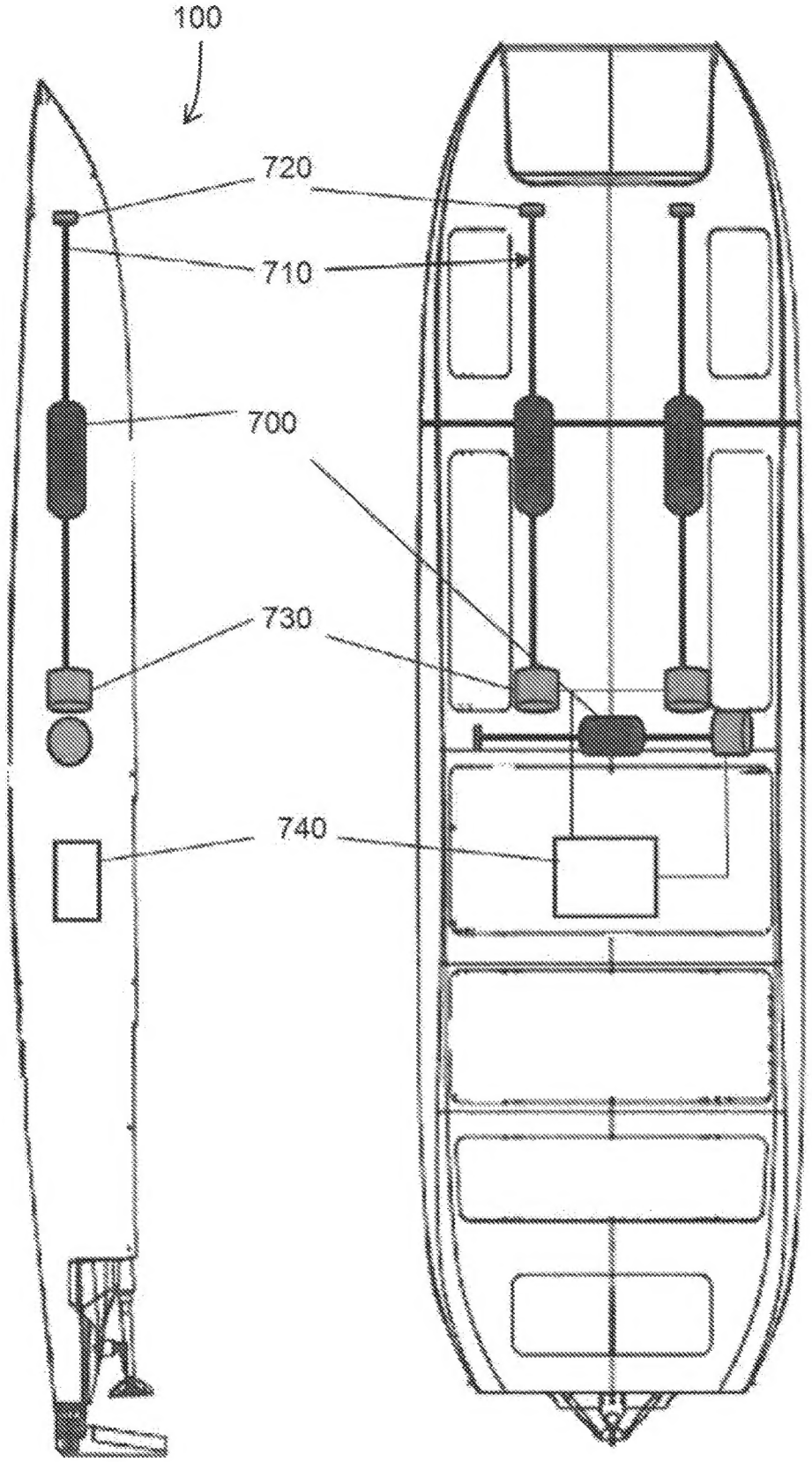

FIG. 7

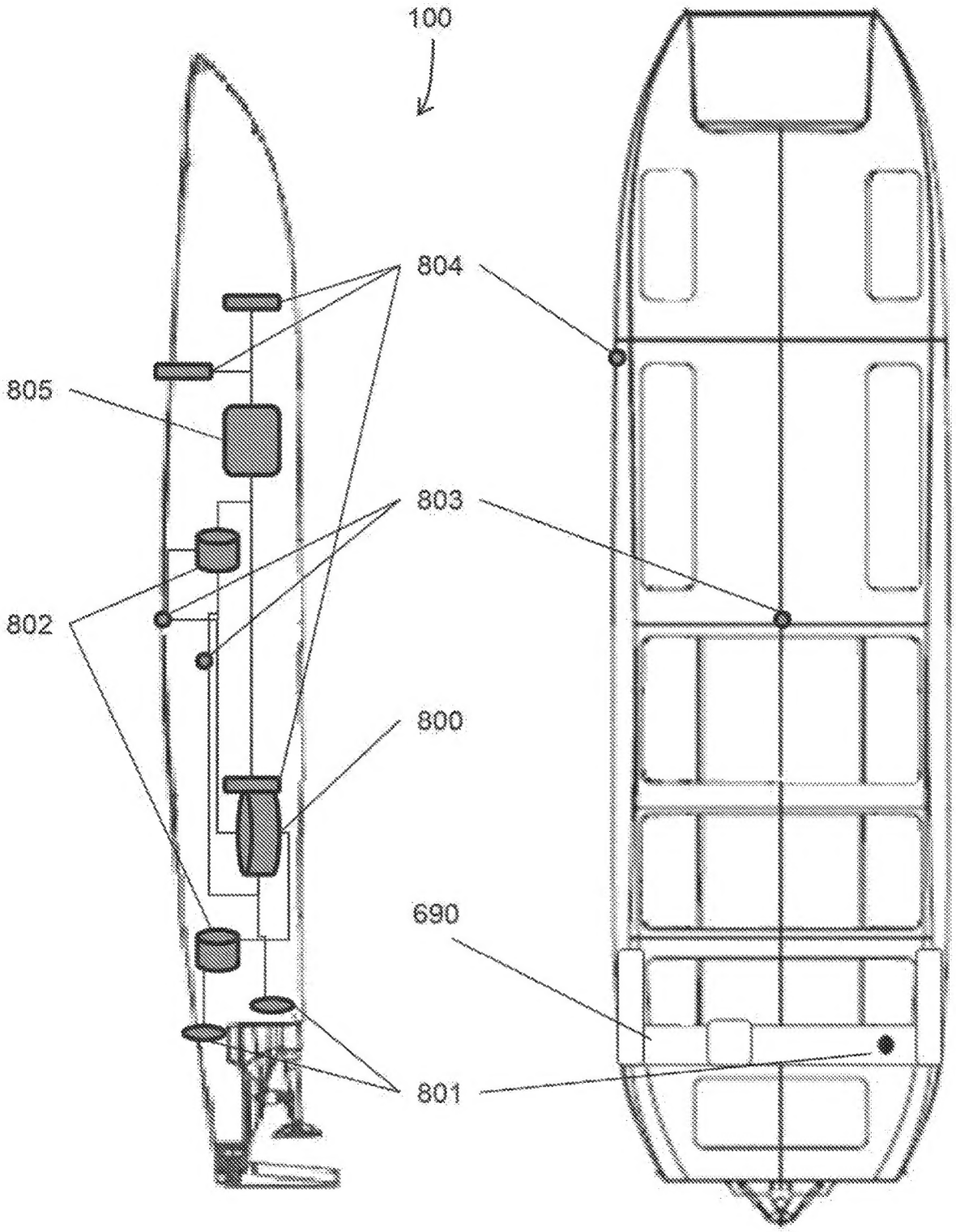

FIG. 8

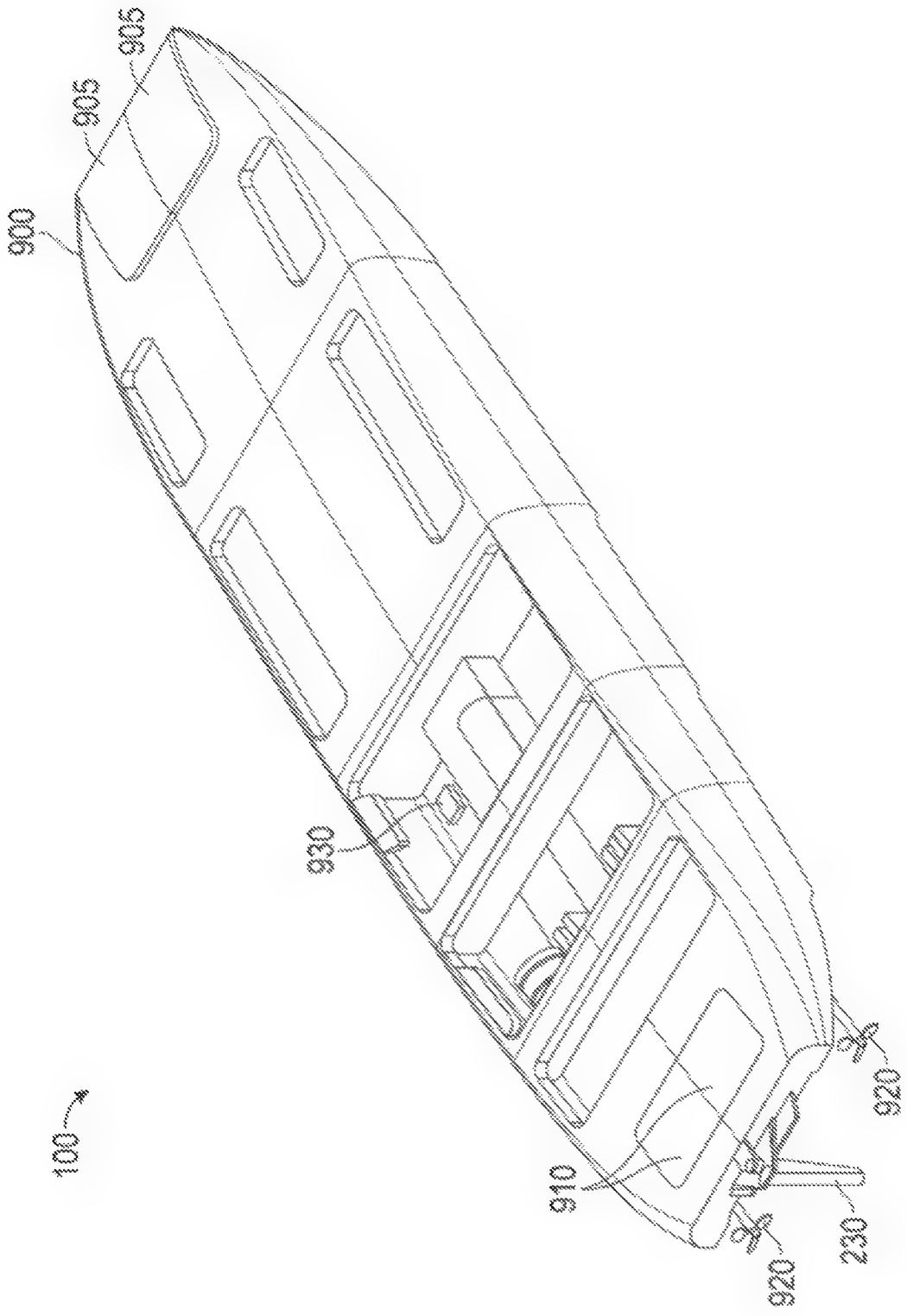

FIG. 9

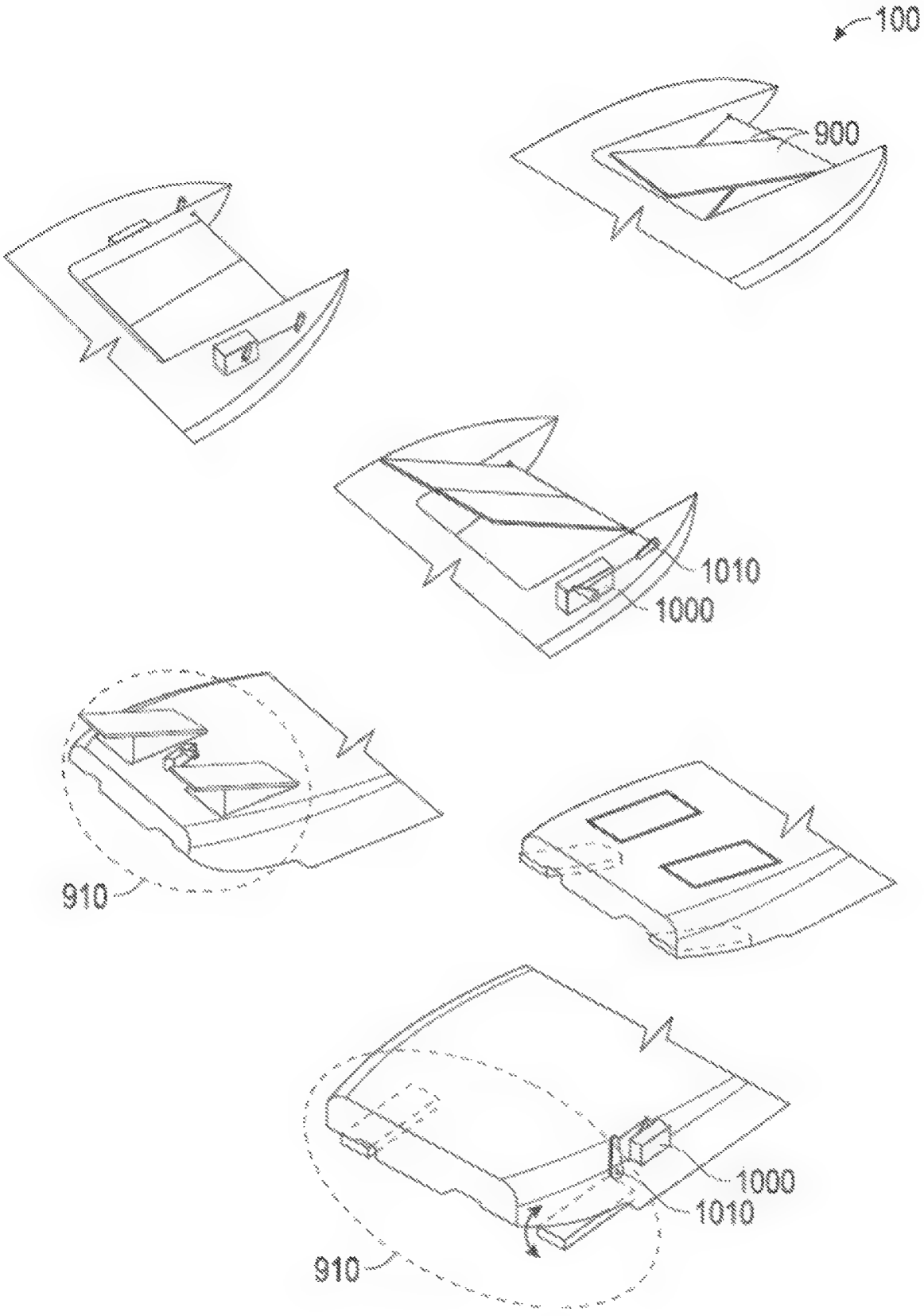

FIG. 10

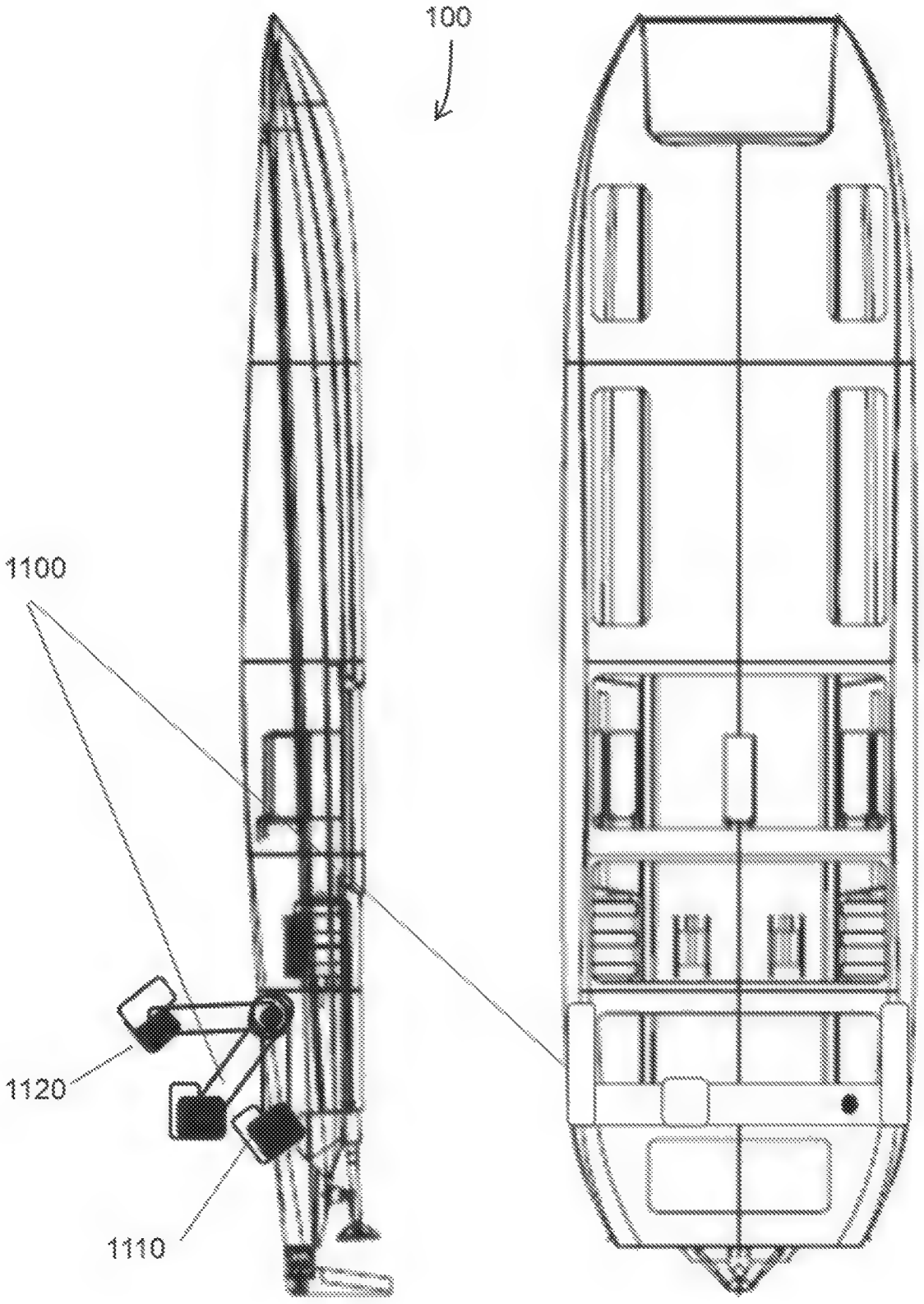

FIG. 11

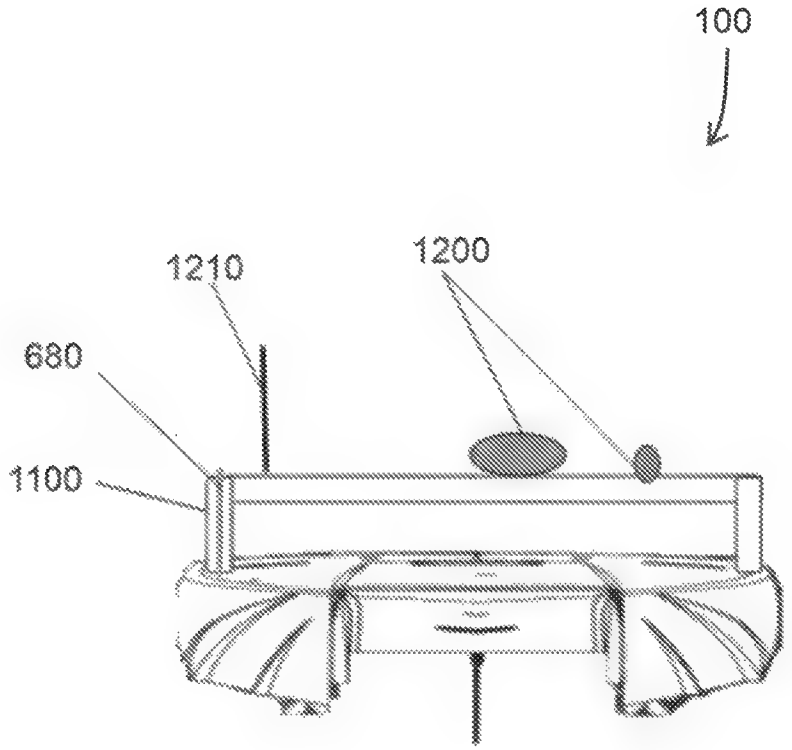

FIG. 12

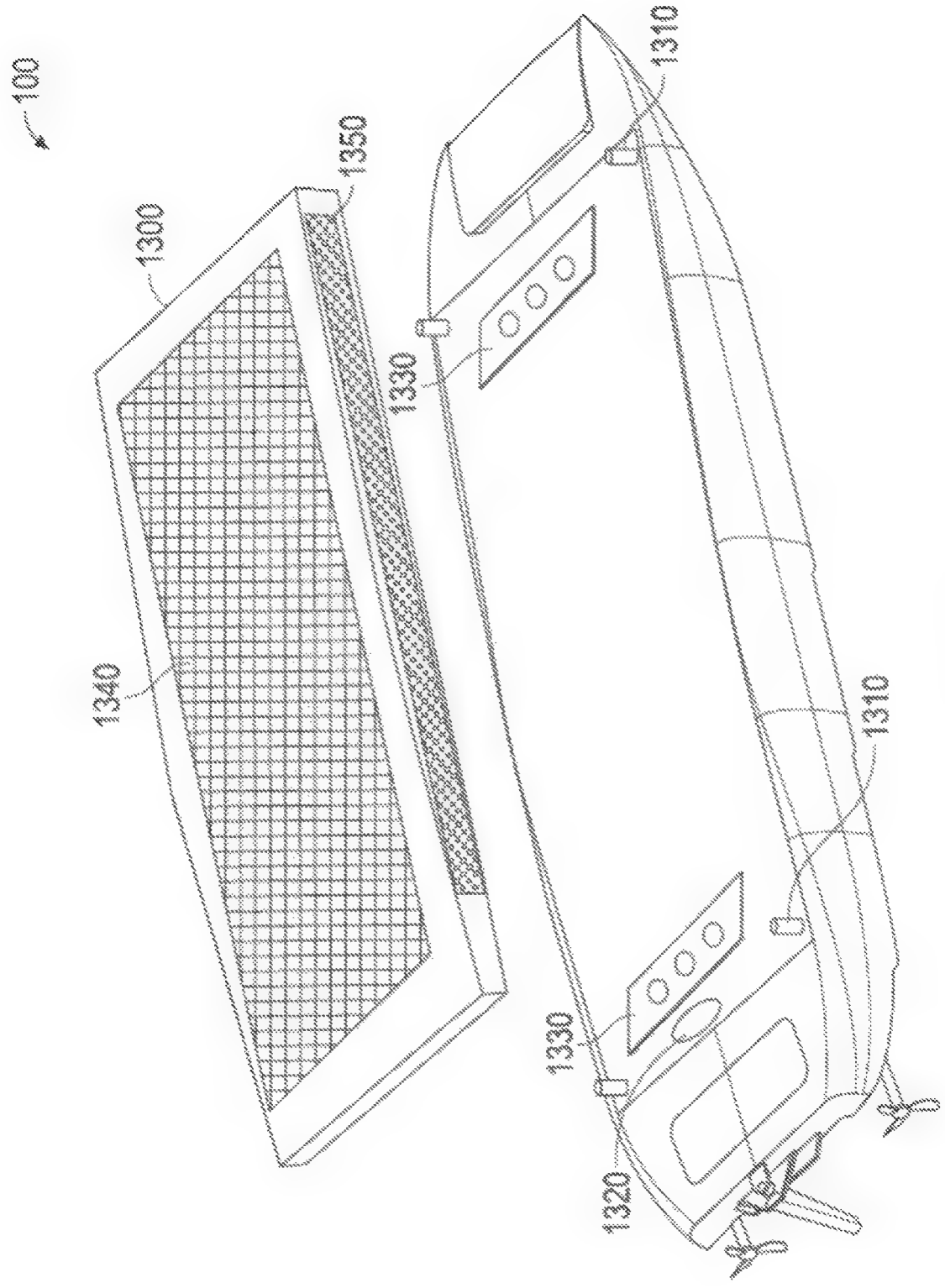

FIG. 13

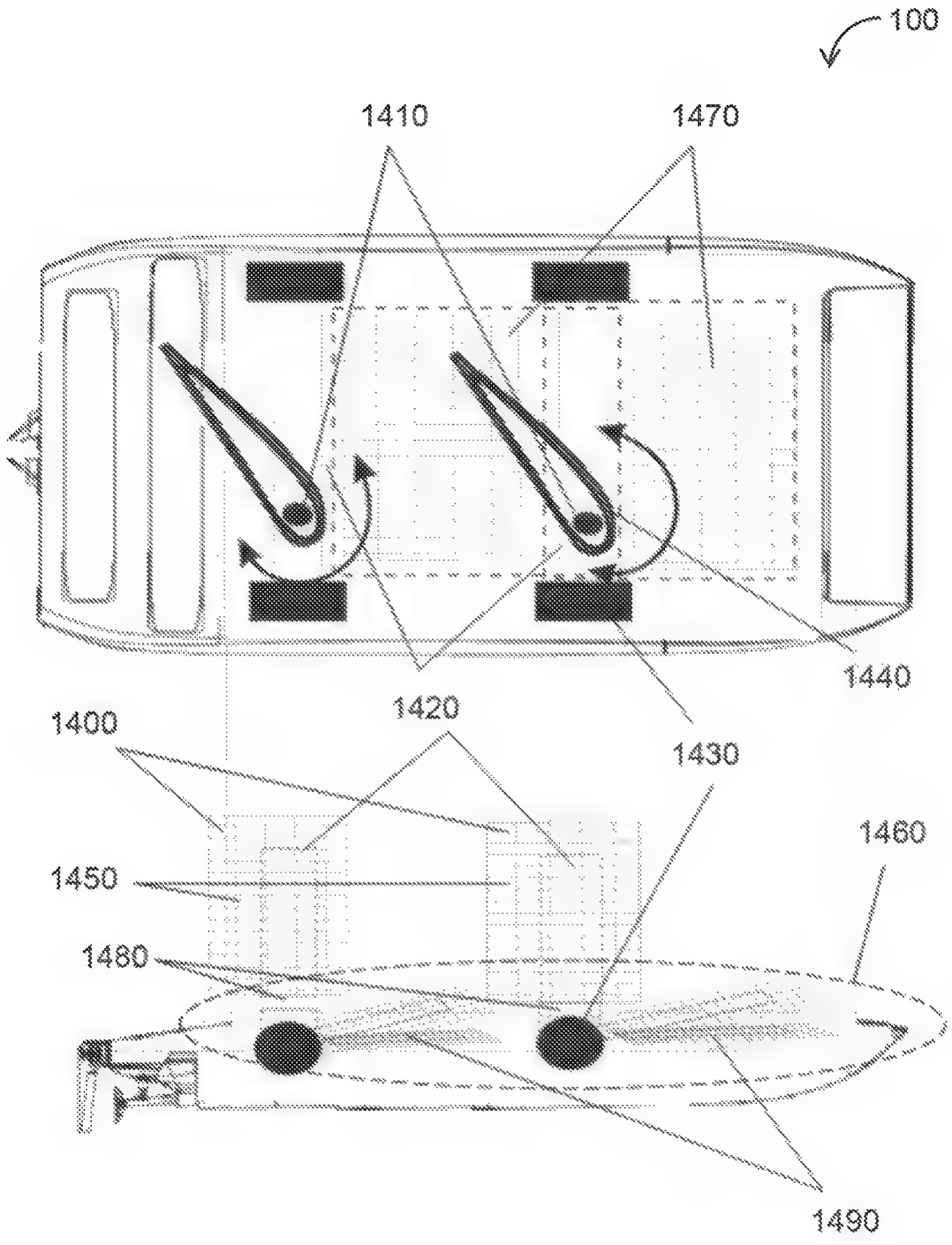

FIG. 14

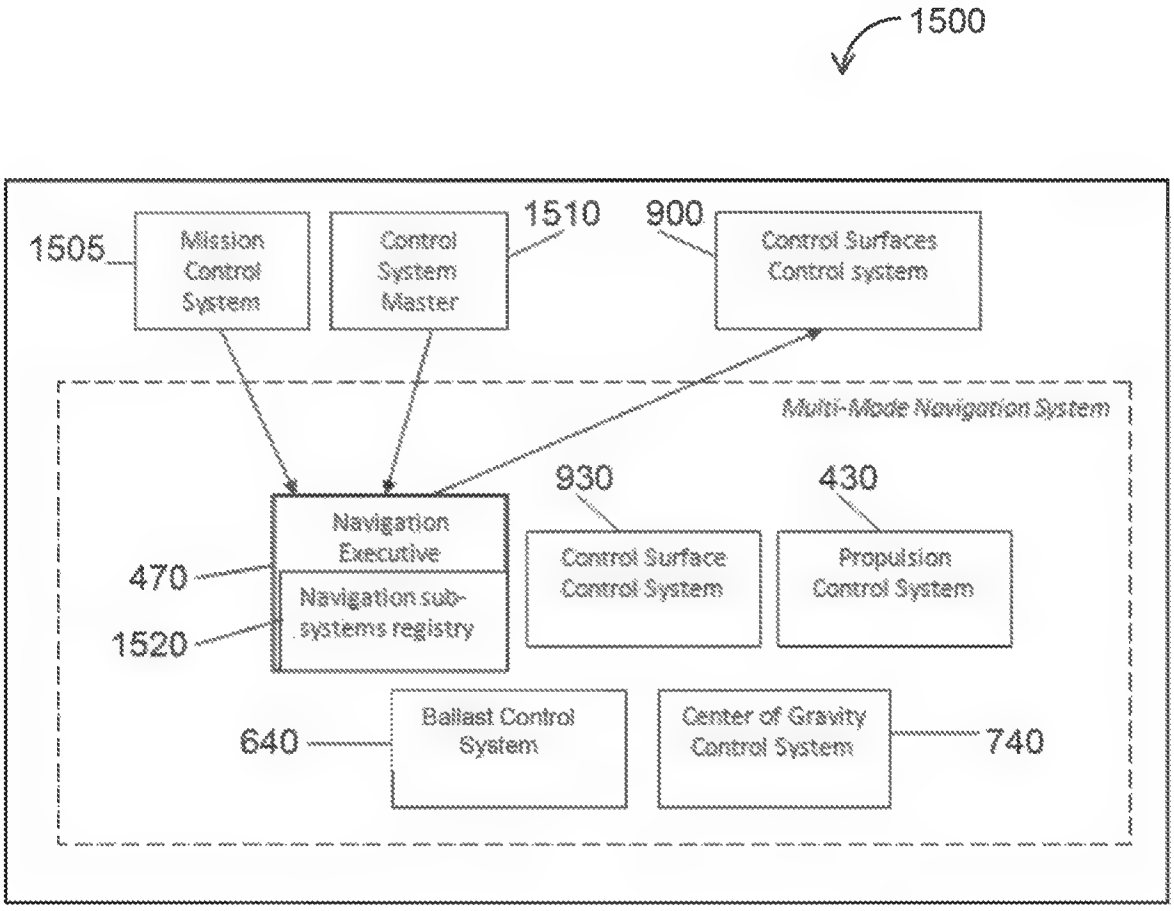
1500
1505
Mission Control System
Control System Master
1510
900
Control Surfaces Control system
Multi-Mode Navigation System
930
430
Navigation Executive
470
Navigation sub-systems registry
1520
Control Surface Control System
Propulsion Control System
640
Ballast Control System
Center of Gravity Control System
740

FIG. 15

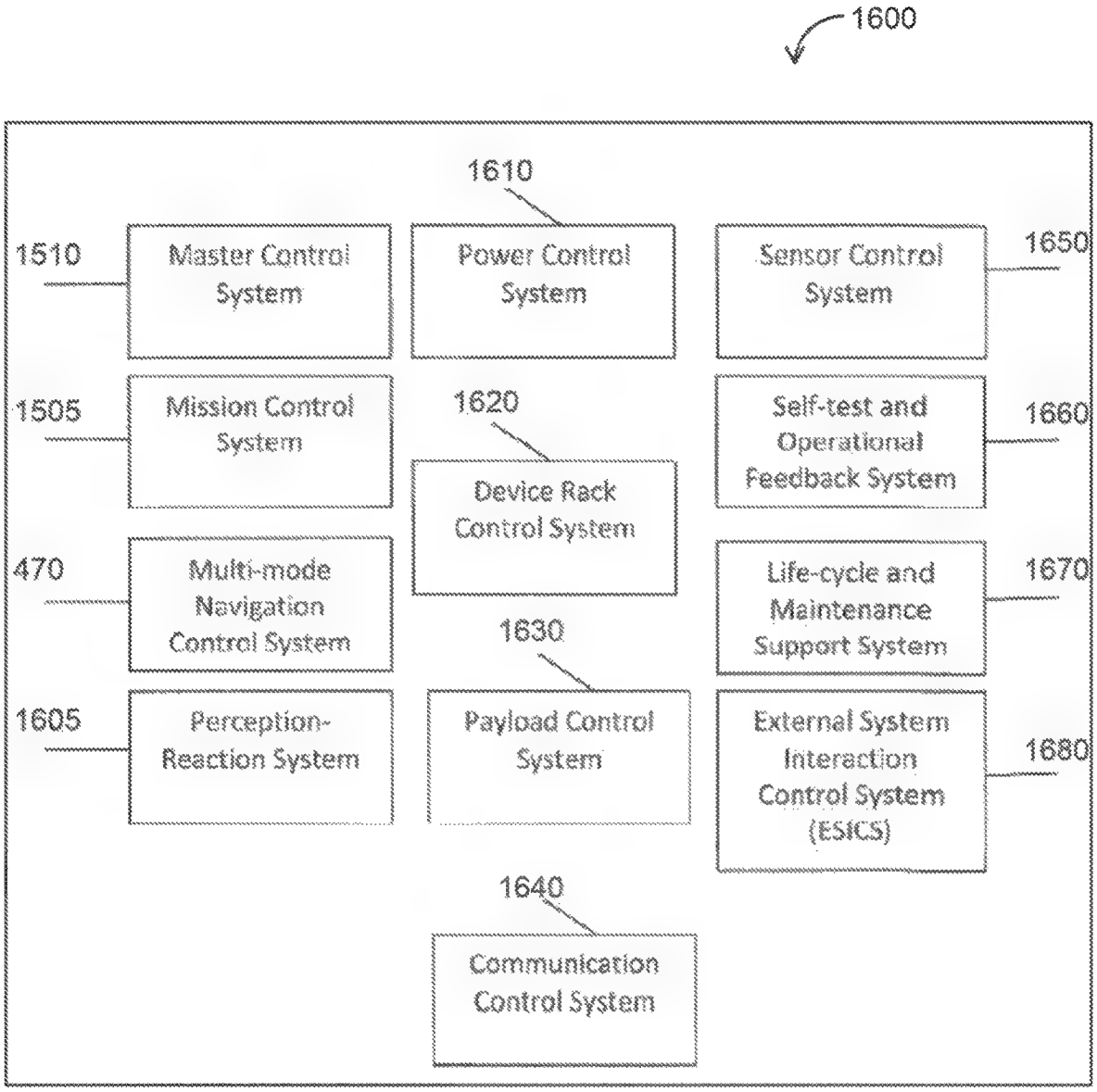
1600
1610
1510
Master Control System
Power Control System
Sensor Control System
1650
1505
Mission Control System
1620
Device Rack Control System
Self-test and Operational Feedback System
1660
470
Multi-mode Navigation Control System
Life-cycle and Maintenance Support System
1670
1630
1605
Perception-Reaction System
Payload Control System
External System Interaction Control System (ESICS)
1680
1640
Communication Control System

FIG. 16

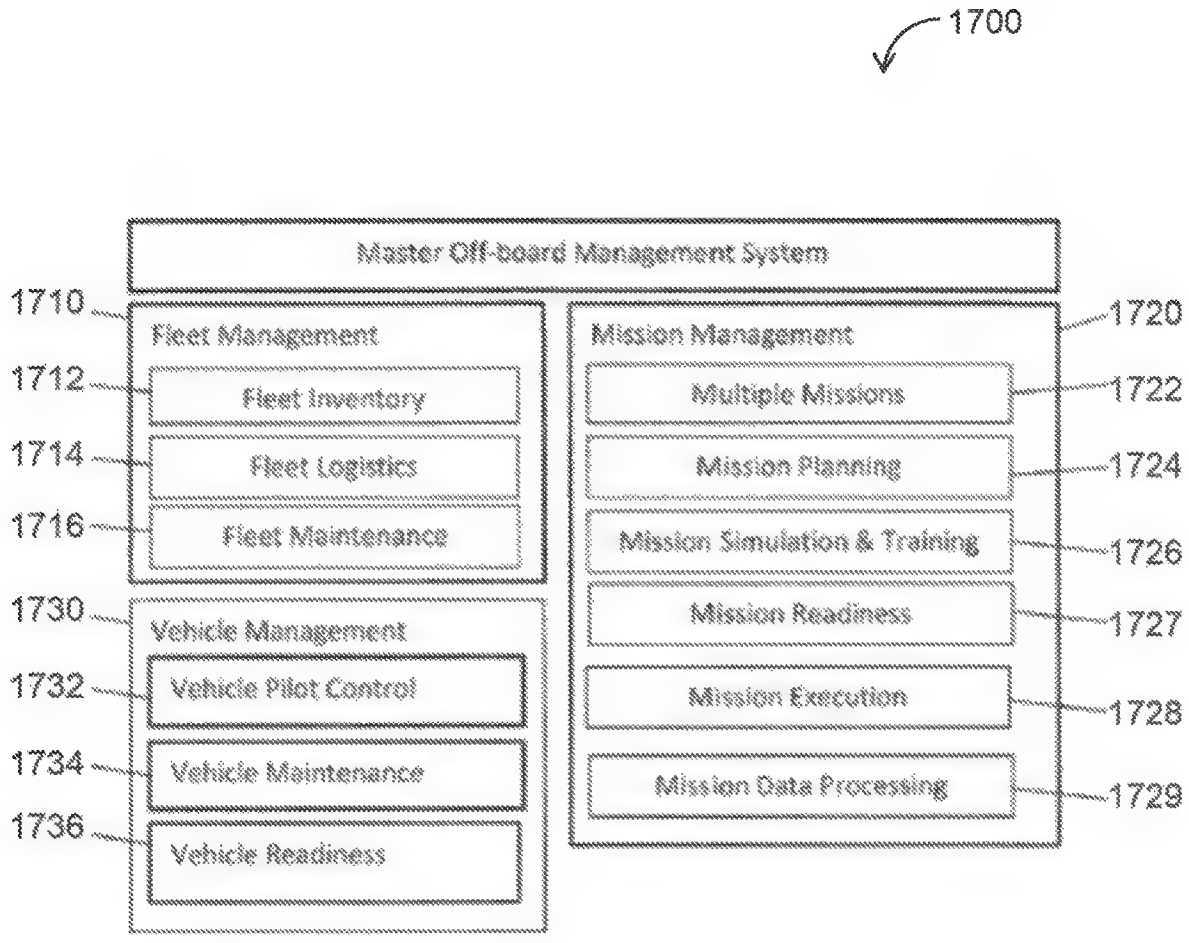
1700
Master Off-board Management System
1710
Fleet Management
1712
Fleet Inventory
1714
Fleet Logistics
1716
Fleet Maintenance
1730
Vehicle Management
1732
Vehicle Pilot Control
1734
Vehicle Maintenance
1736
Vehicle Readiness
1720
Mission Management
1722
Multiple Missions
1724
Mission Planning
1726
Mission Simulation & Training
1727
Mission Readiness
1728
Mission Execution
1729
Mission Data Processing

FIG. 17

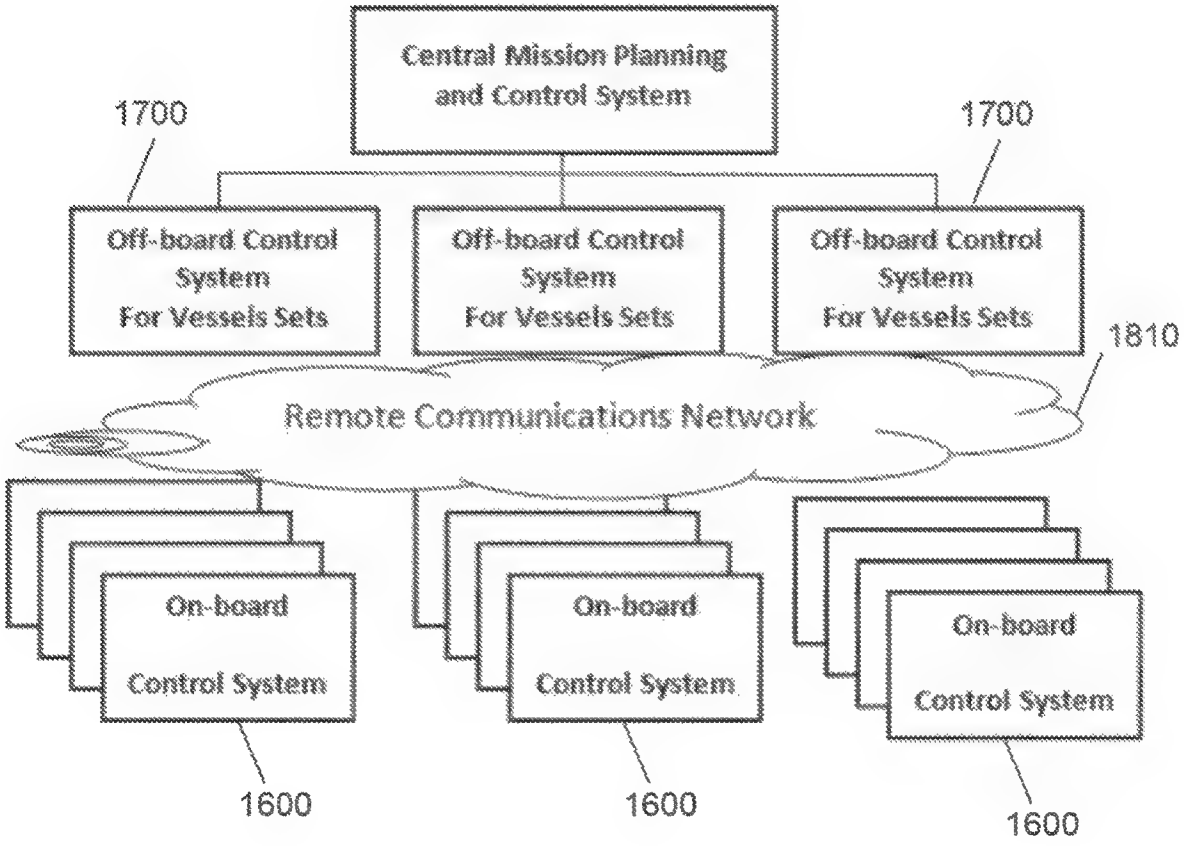
Central Mission Planning and Control System
1700
1700
Off-board Control System For Vessels Sets
Off-board Control System For Vessels Sets
Off-board Control System For Vessels Sets
1810
Remote Communications Network
On-board Control System
On-board Control System
On-board Control System
1600
1600
1600

FIG. 18

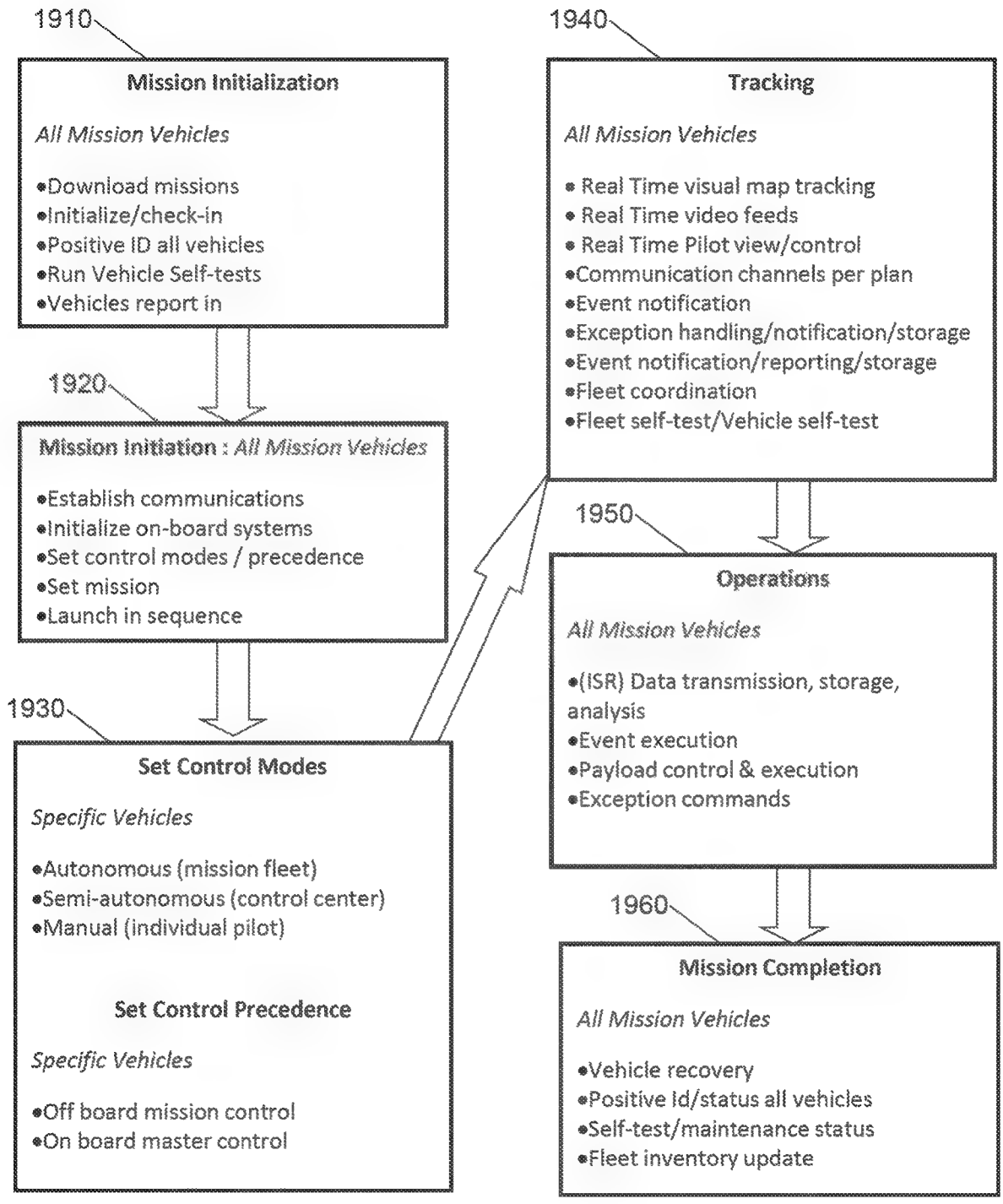
1910
Mission Initialization
All Mission Vehicles
•Download missions
•Initialize/check-in
•Positive ID all vehicles
•Run Vehicle Self-tests
•Vehicles report in
1920
Mission Initiation : All Mission Vehicles
•Establish communications
•Initialize on-board systems
•Set control modes / precedence
•Set mission
•Launch in sequence
1930
Set Control Modes
Specific Vehicles
•Autonomous (mission fleet)
•Semi-autonomous (control center)
•Manual (individual pilot)
Set Control Precedence
Specific Vehicles
•Off board mission control
•On board master control
1940
Tracking
All Mission Vehicles
• Real Time visual map tracking
• Real Time video feeds
• Real Time Pilot view/control
•Communication channels per plan
•Event notification
•Exception handling/notification/storage
•Event notification/reporting/storage
•Fleet coordination
•Fleet self-test/Vehicle self-test
1950
Operations
All Mission Vehicles
•(ISR) Data transmission, storage, analysis
•Event execution
•Payload control & execution
•Exception commands
1960
Mission Completion
All Mission Vehicles
•Vehicle recovery
•Positive Id/status all vehicles
•Self-test/maintenance status
•Fleet inventory update

FIG. 19

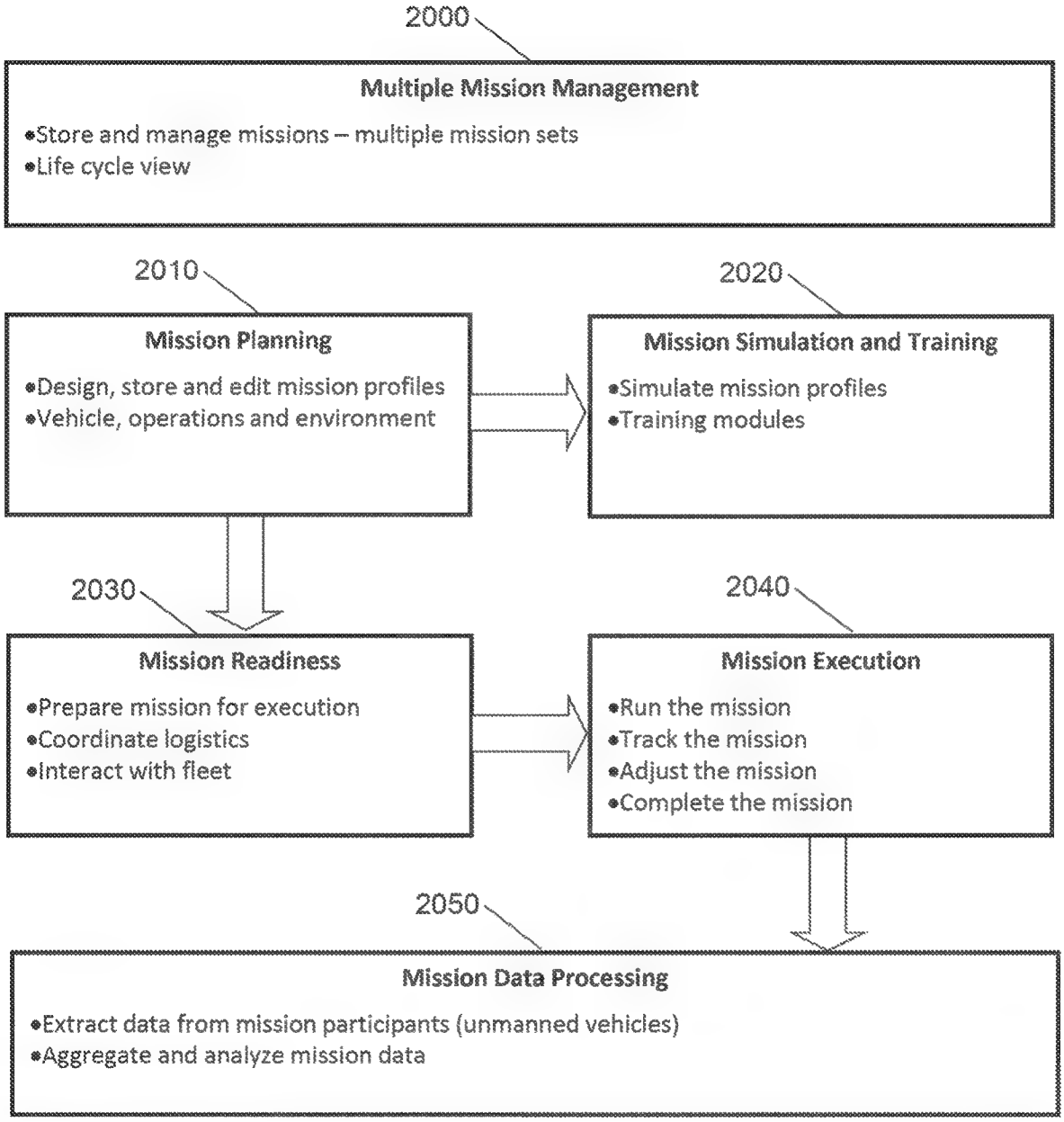
2000
Multiple Mission Management
•Store and manage missions – multiple mission sets
•Life cycle view
2010
Mission Planning
•Design, store and edit mission profiles
•Vehicle, operations and environment
2020
Mission Simulation and Training
•Simulate mission profiles
•Training modules
2030
Mission Readiness
•Prepare mission for execution
•Coordinate logistics
•Interact with fleet
2040
Mission Execution
•Run the mission
•Track the mission
•Adjust the mission
•Complete the mission
2050
Mission Data Processing
•Extract data from mission participants (unmanned vehicles)
•Aggregate and analyze mission data

FIG. 20

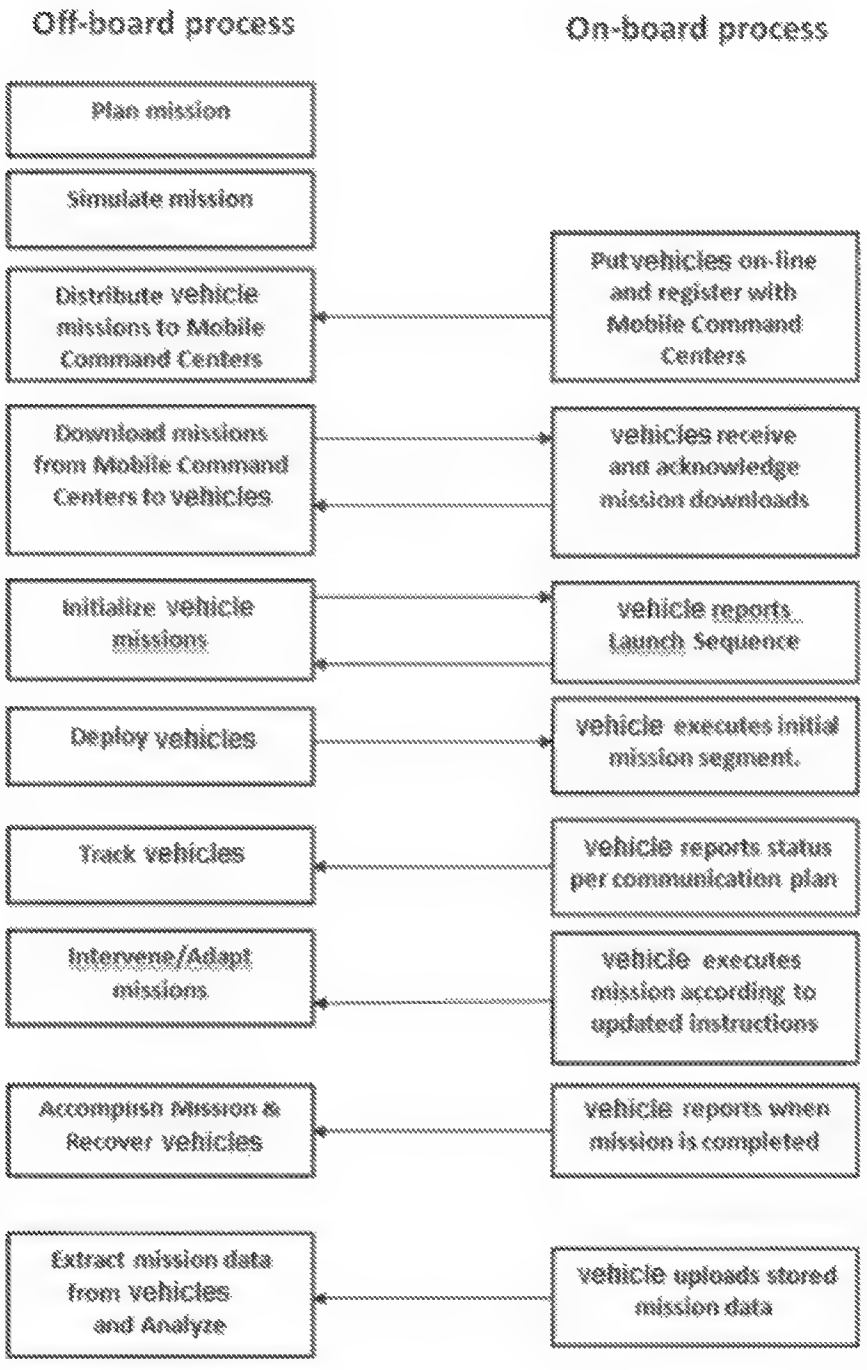
Off-board process
On-board process
Plan mission
Simulate mission
Distribute vehicle missions to Mobile Command Centers
Put vehicles on-line and register with Mobile Command Centers
Download missions from Mobile Command Centers to vehicles
vehicles receive and acknowledge mission downloads
Initialize vehicle missions
vehicle reports Launch Sequence
Deploy vehicles
vehicle executes initial mission segment.
Track vehicles
vehicle reports status per communication plan
Intervene/Adapt missions
vehicle executes mission according to updated instructions
Accomplish Mission & Recover vehicles
vehicle reports when mission is completed
Extract mission data from vehicles and Analyze
vehicle uploads stored mission data

FIG. 21

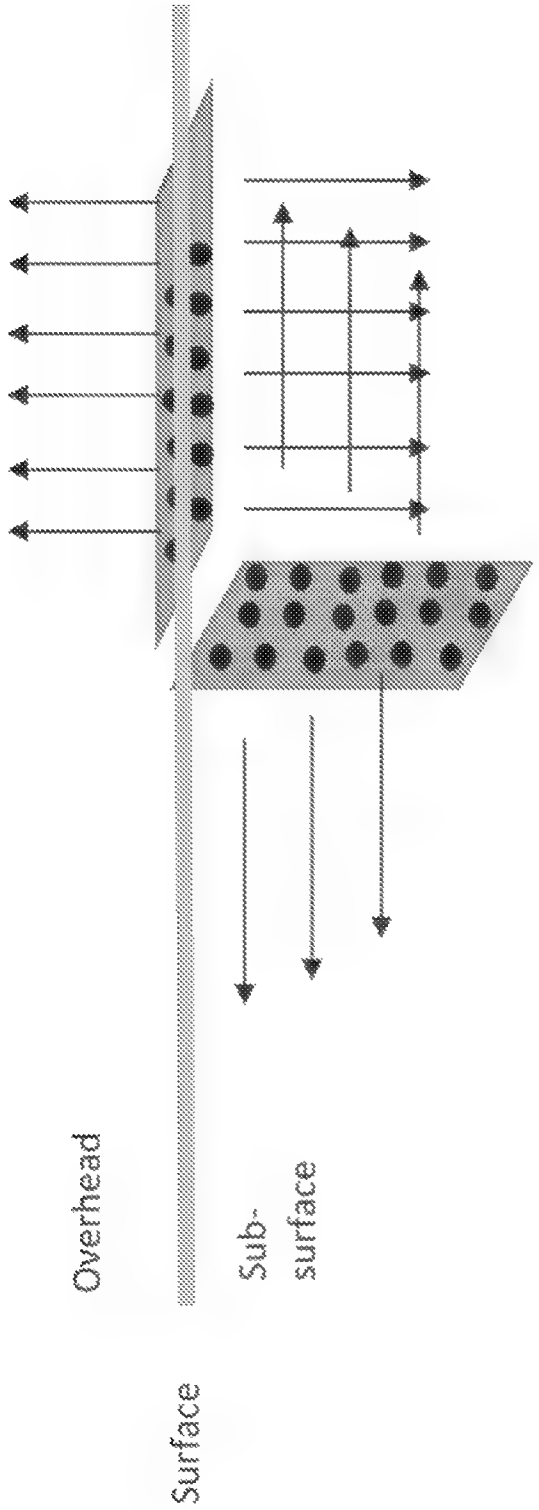

FIG. 22

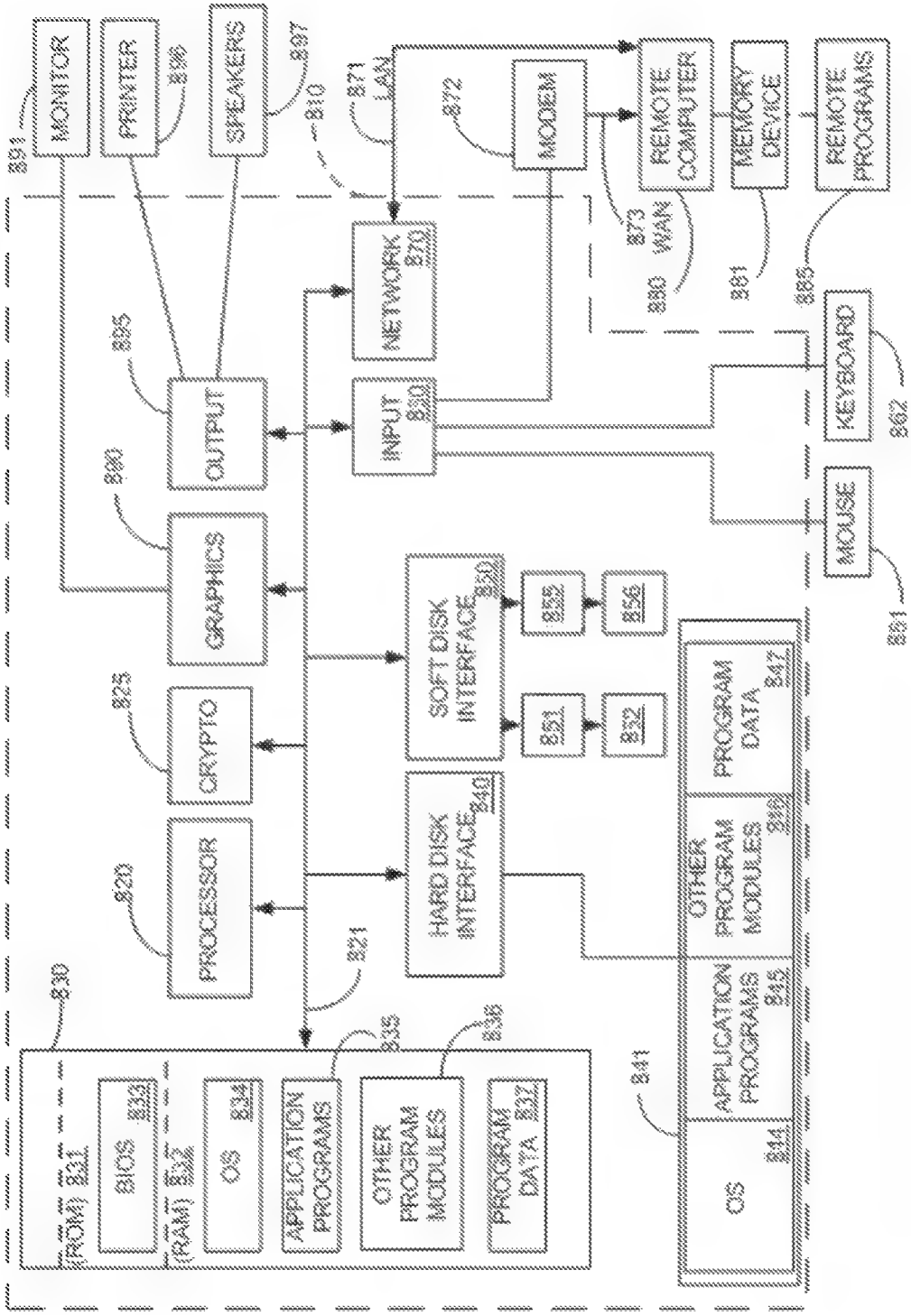
MONITOR
891
PRINTER
896
SPEAKERS
897
810
871
LAN
872
MODEM
REMOTE COMPUTER
MEMORY DEVICE
REMOTE PROGRAMS
873
WAN
880
881
885
NETWORK 870
INPUT 830
OUTPUT
835
890
GRAPHICS
KEYBOARD
862
MOUSE
861
SOFT DISK INTERFACE 850
852
856
851
853
CRYPTO
825
PROCESSOR
820
HARD DISK INTERFACE 840
821
PROGRAM DATA 847
OTHER PROGRAM MODULES 846
APPLICATION PROGRAMS 845
OS 844
841
830
(ROM) 831
BIOS 833
(RAM) 832
OS 834
APPLICATION PROGRAMS
835
OTHER PROGRAM MODULES
836
PROGRAM DATA 837

FIG. 23

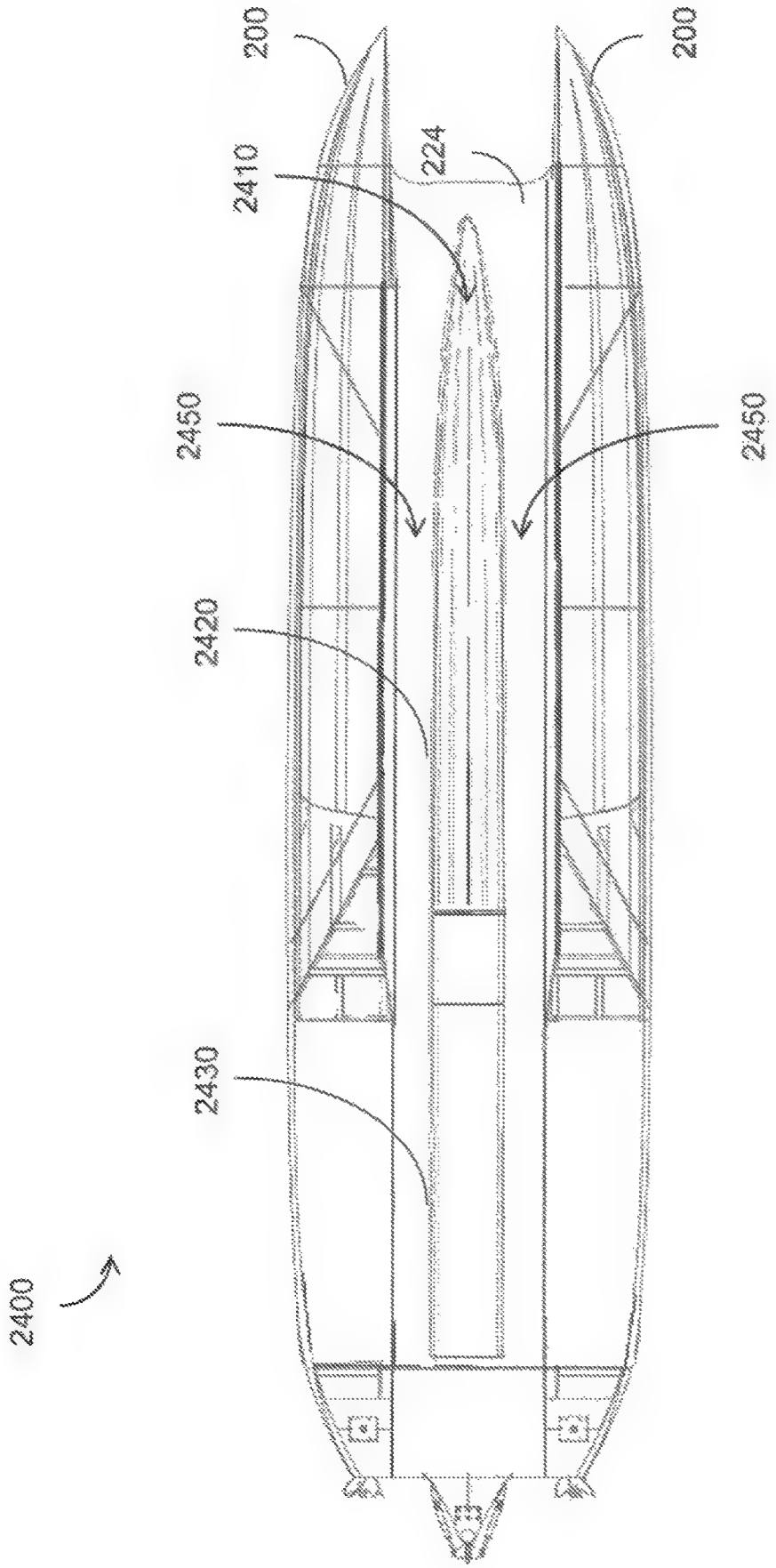

FIG. 24

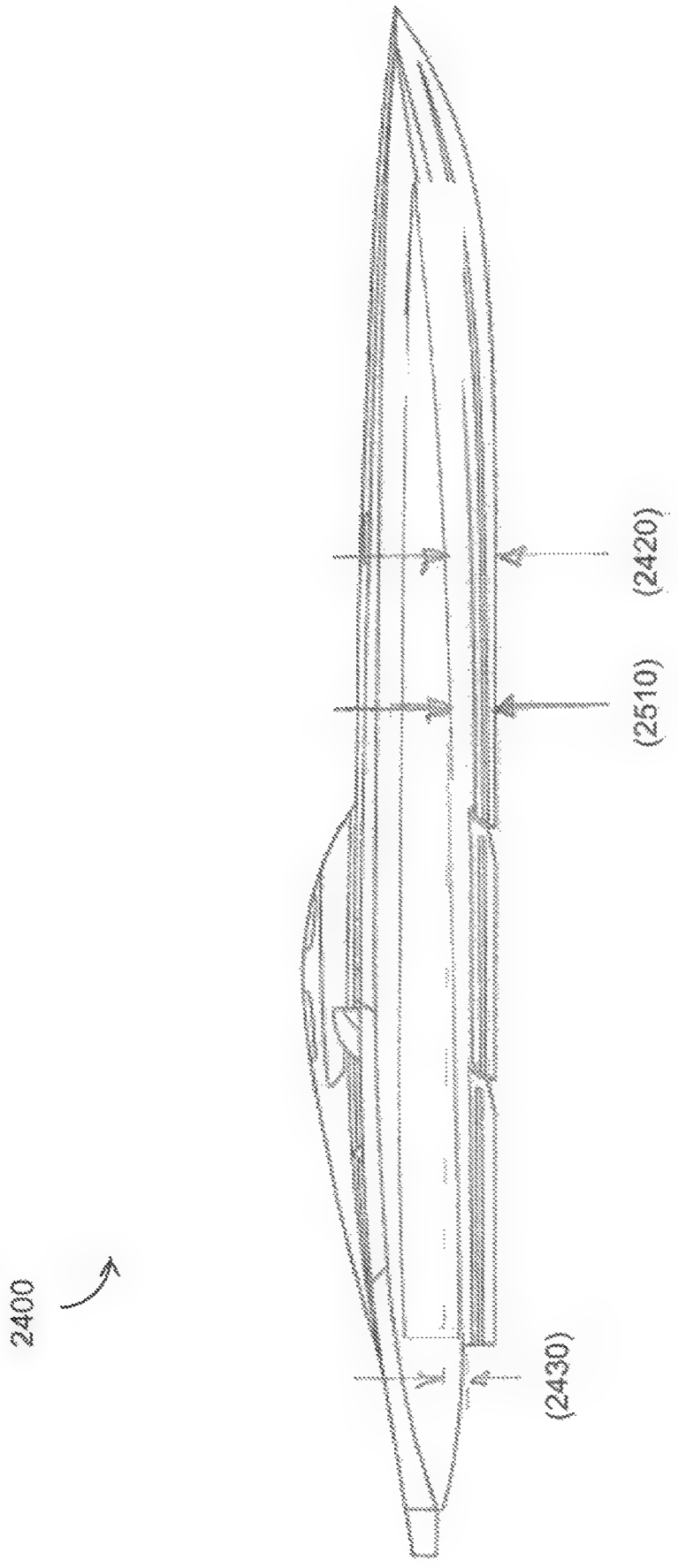

FIG. 25

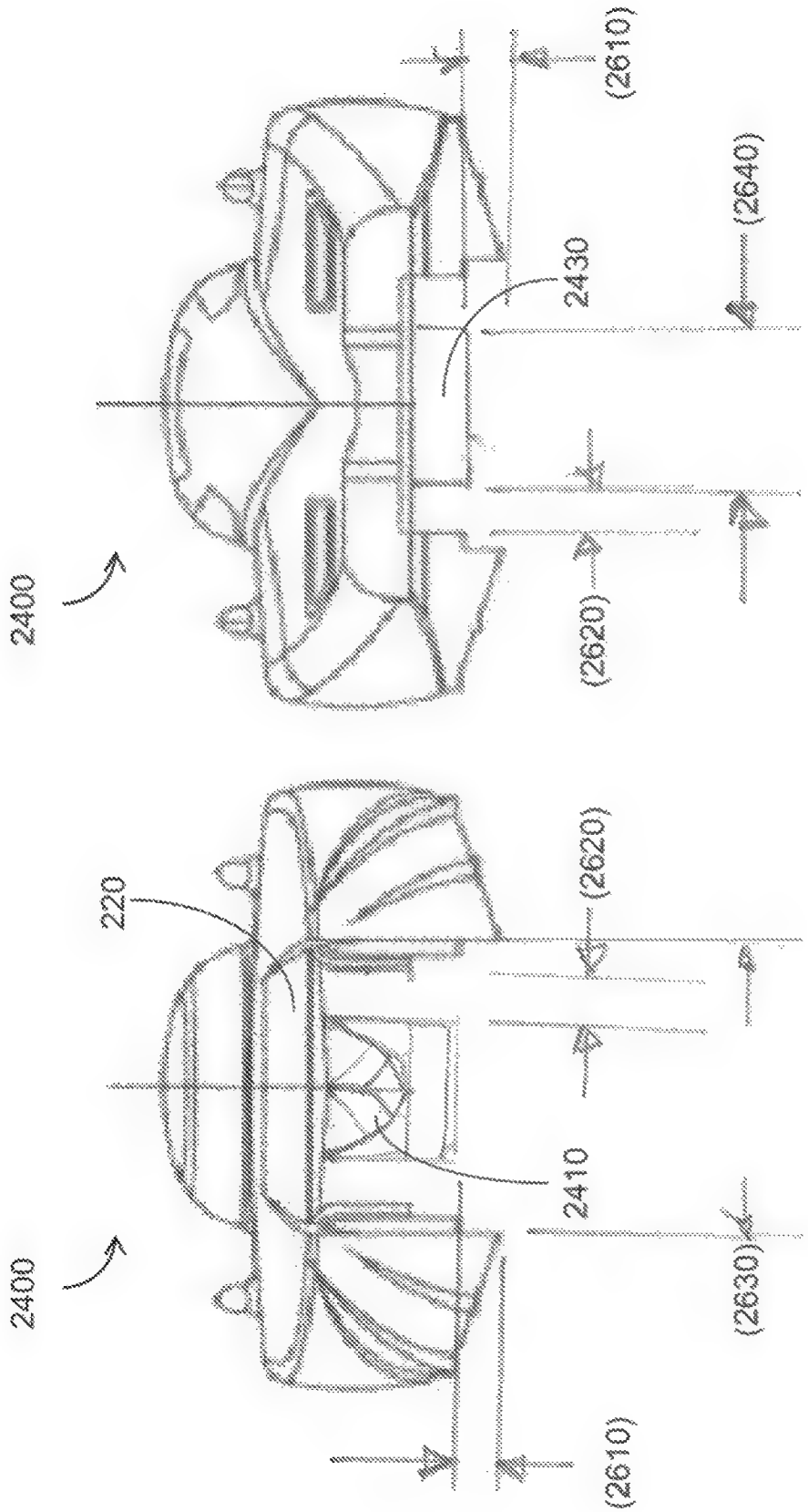

FIG. 26A

FIG. 26B

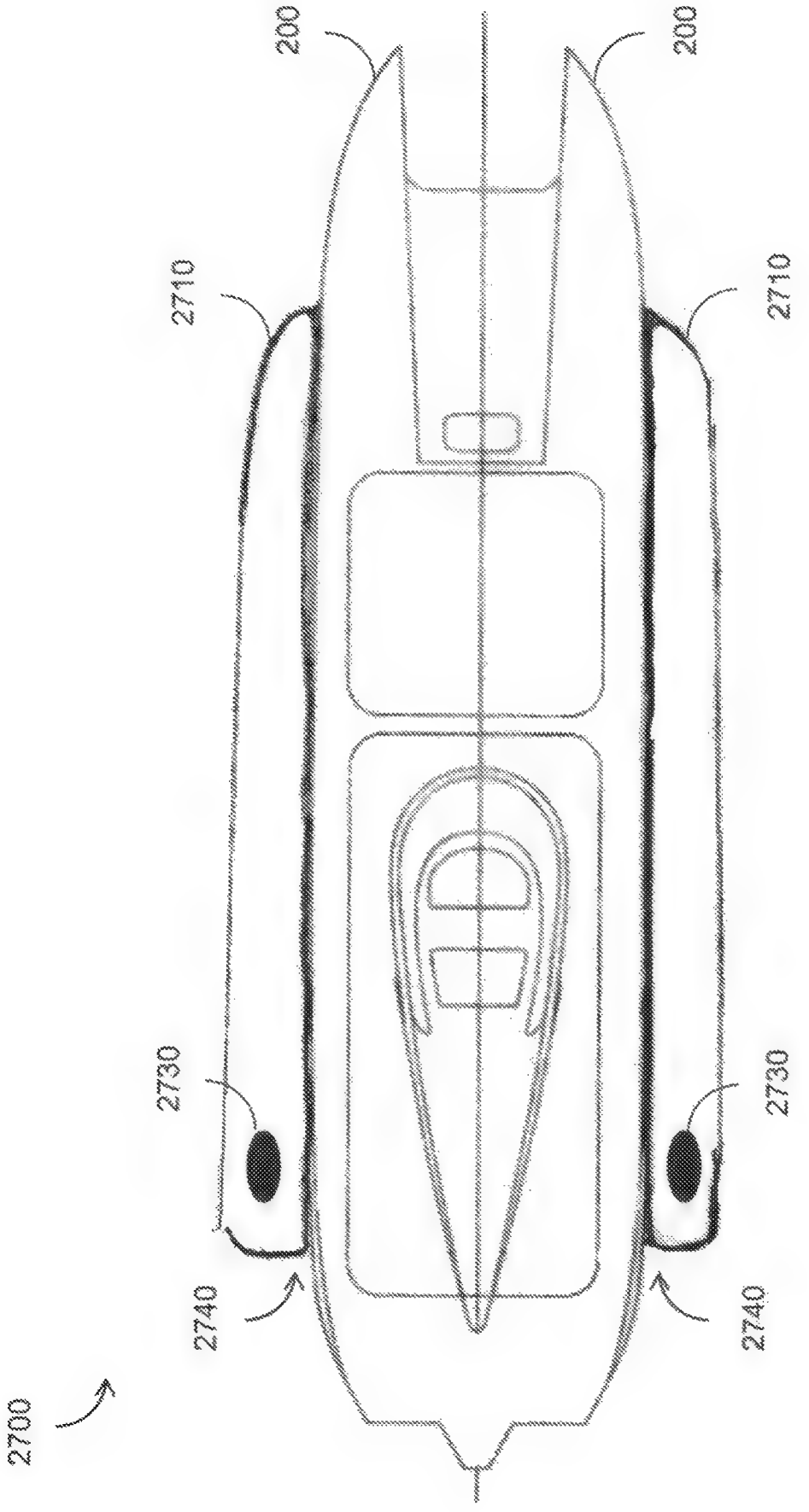

FIG. 27

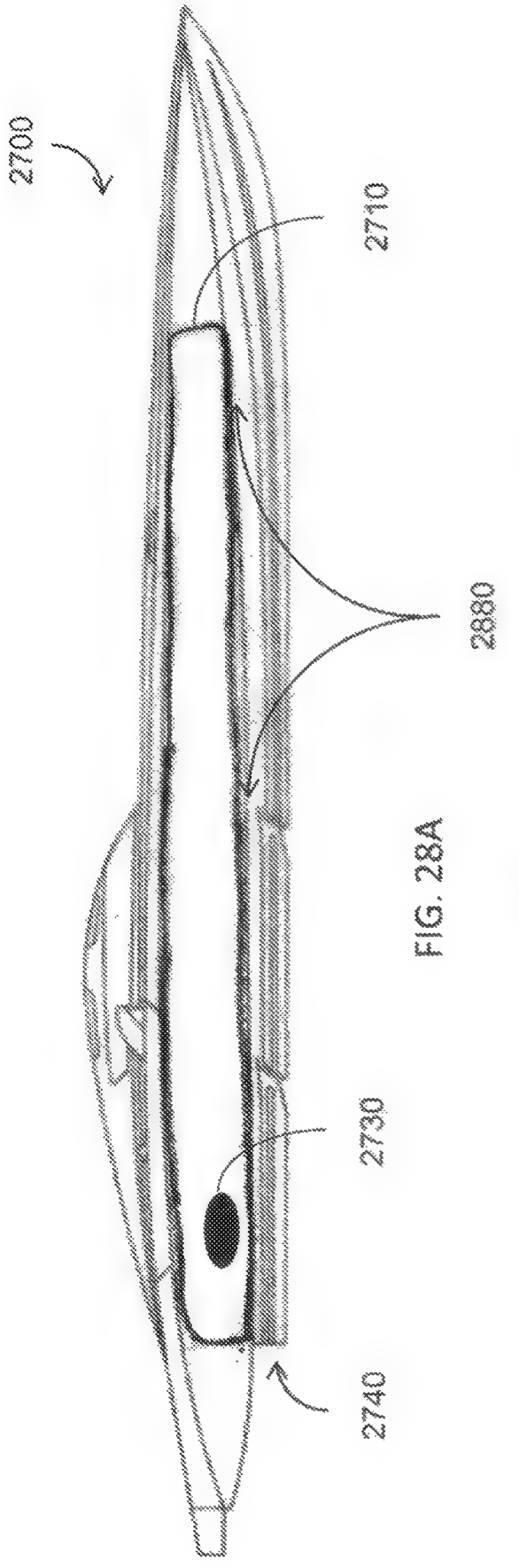

FIG. 28A

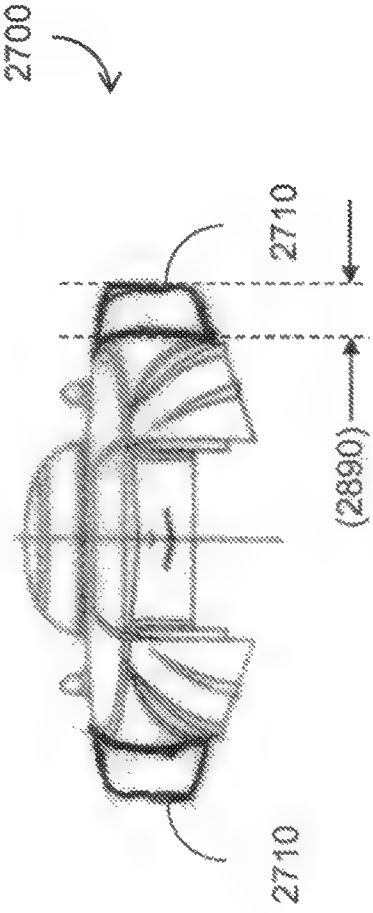

FIG. 28B

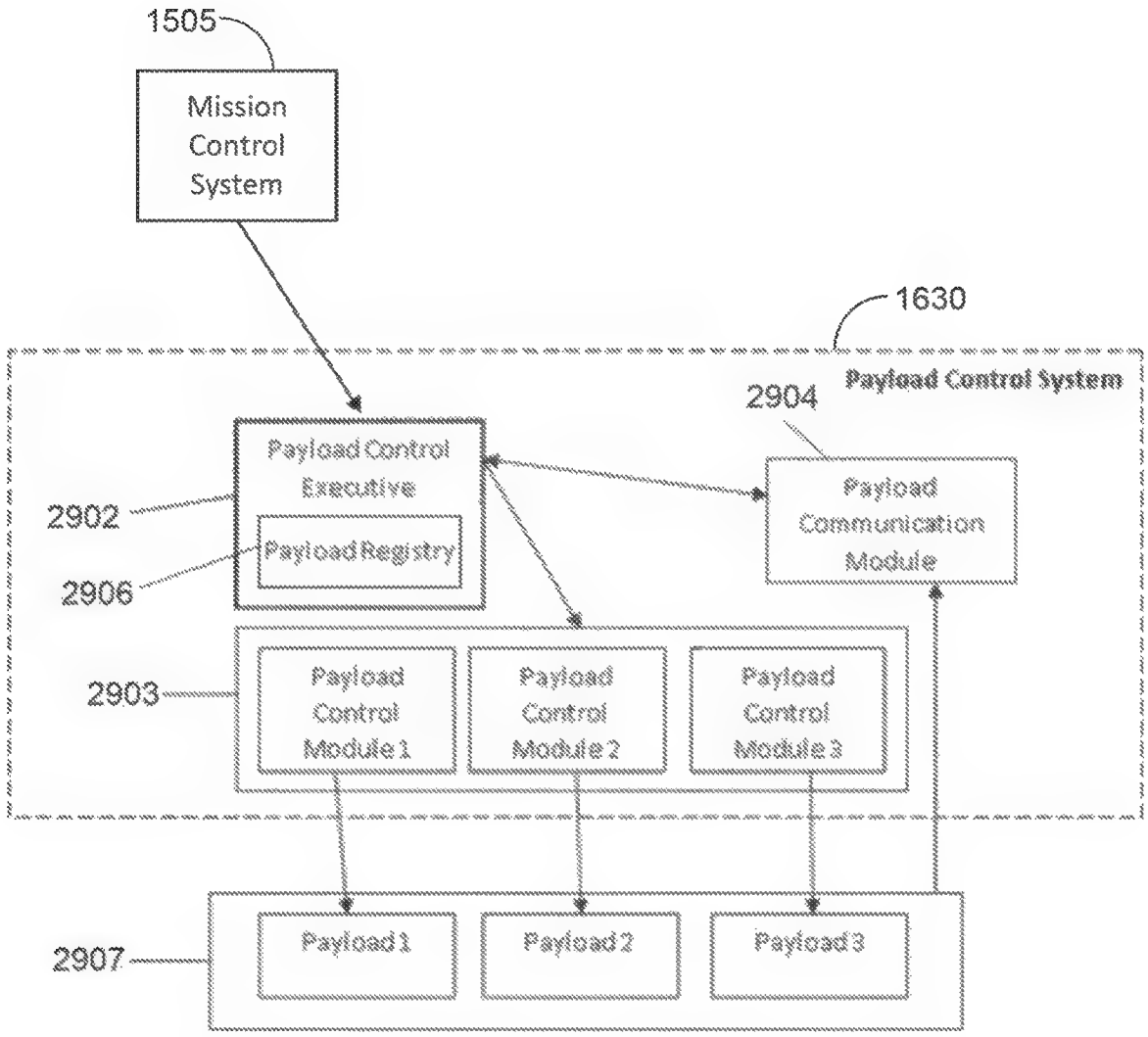
1505
Mission Control System
1630
Payload Control System
2904
Payload Control Executive
2902
Payload Registry
2906
Payload Communication Module
2903
Payload Control Module 1
Payload Control Module 2
Payload Control Module 3
2907
Payload 1
Payload 2
Payload 3

FIG. 29

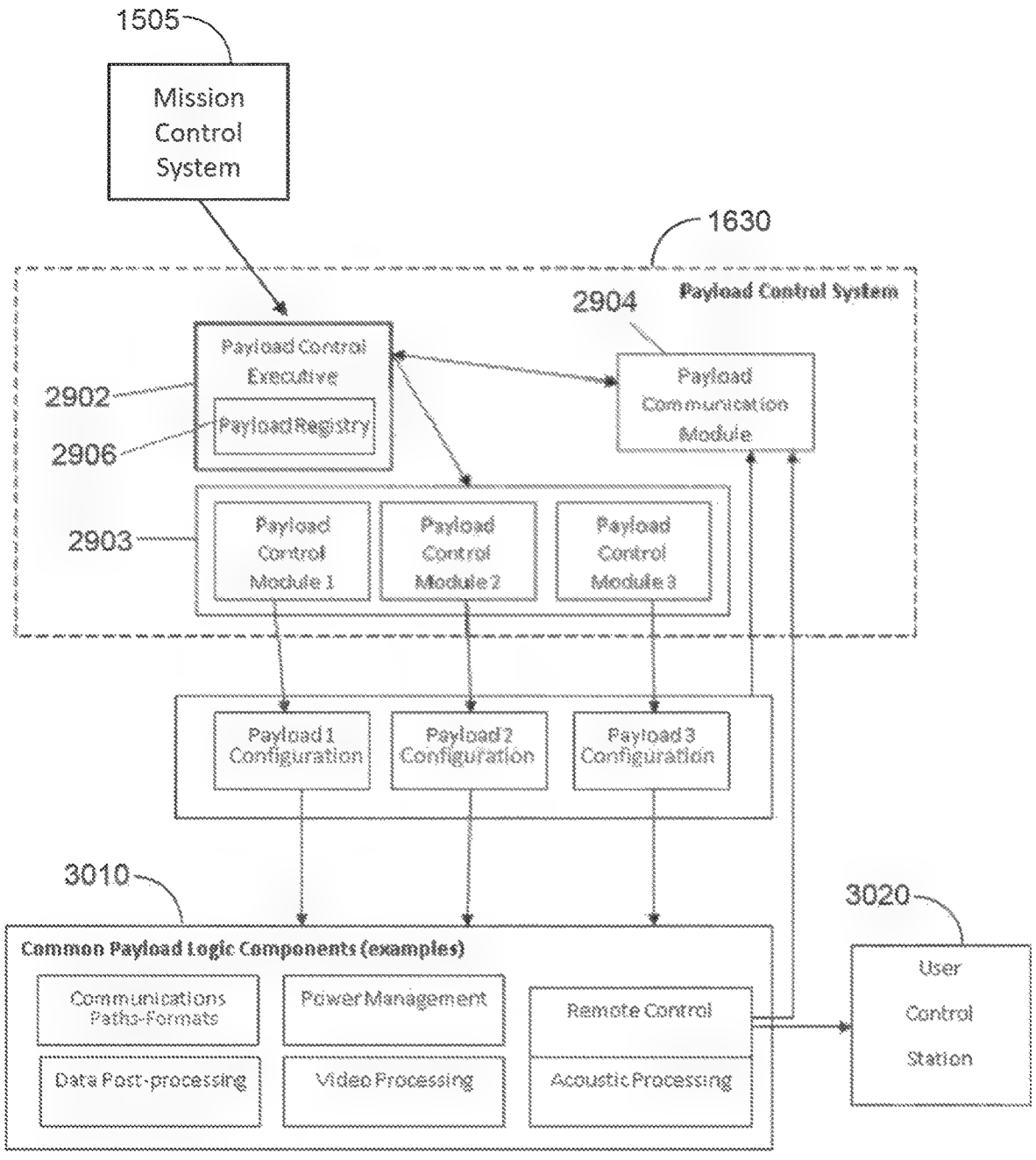
1505
Mission Control System
1630
2904
Payload Control System
Payload Control Executive
Payload Registry
Payload Communication Module
2902
2906
2903
Payload Control Module 1
Payload Control Module 2
Payload Control Module 3
Payload 1 Configuration
Payload 2 Configuration
Payload 3 Configuration
3010
Common Payload Logic Components (examples)
Communications Paths-Formats
Power Management
Remote Control
Data Post-processing
Video Processing
Acoustic Processing
3020
User Control Station

FIG. 30

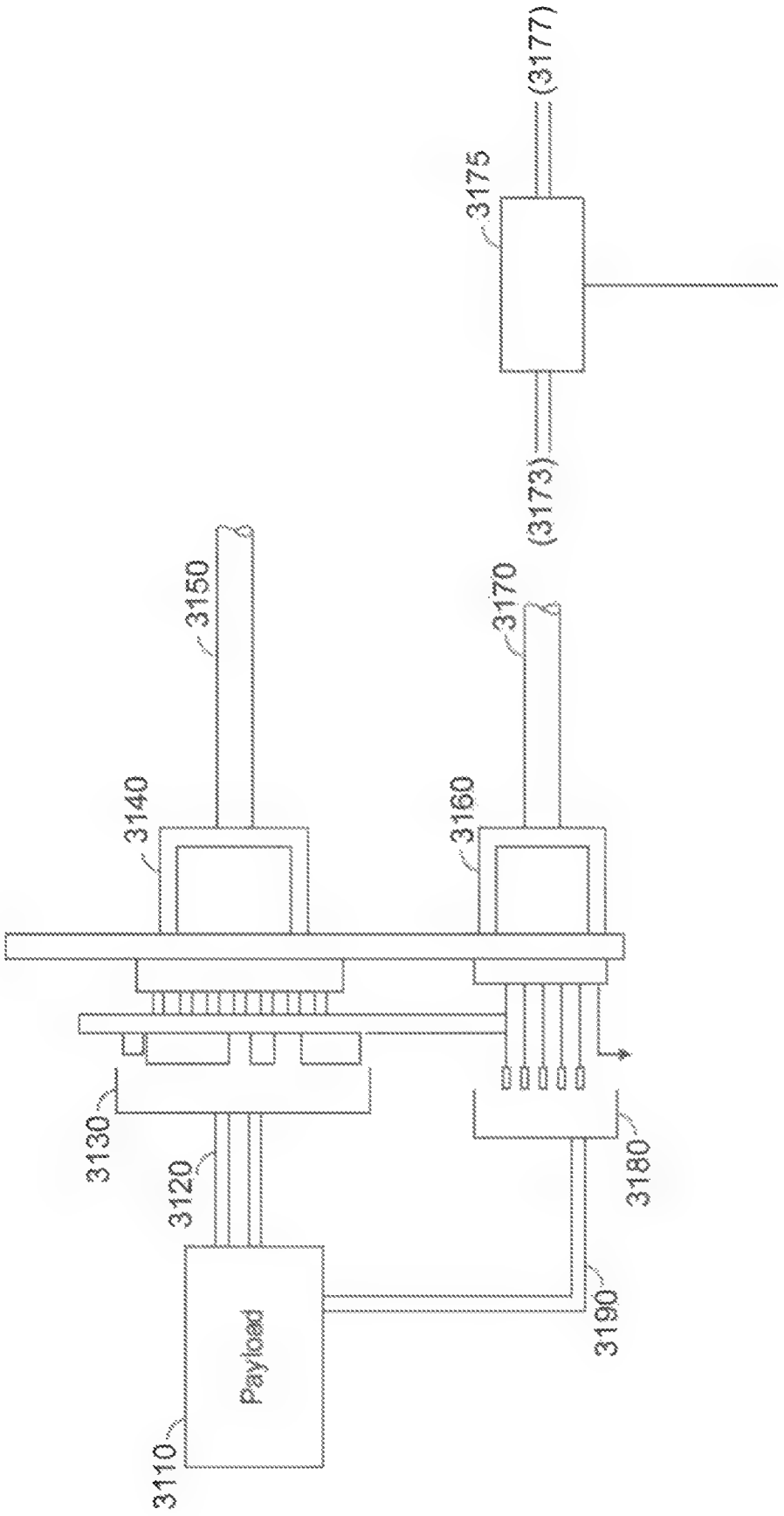
(3177)
3175
(3173)
3150
3170
3140
3160
3130
3120
3180
3190
Payload
3110

FIG. 31

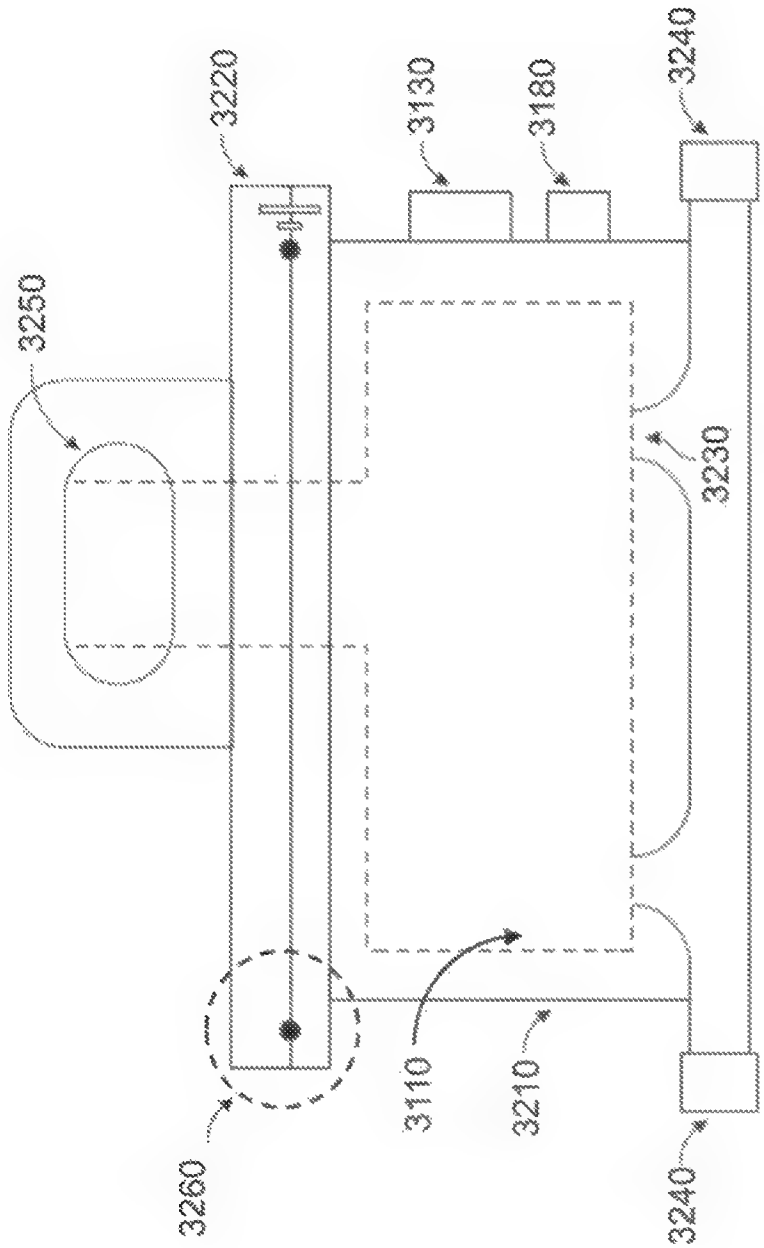

FIG. 32

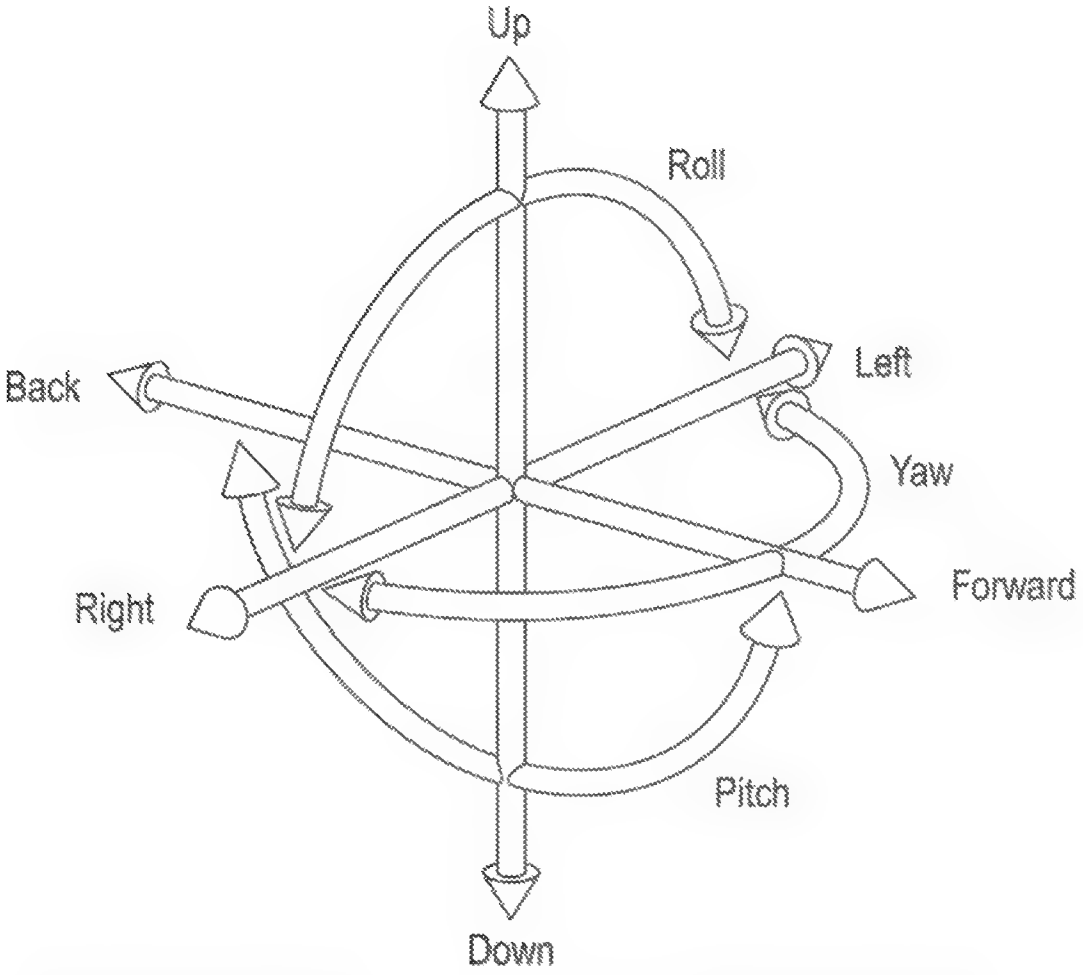
Up
Roll
Back
Left
Yaw
Right
Forward
Pitch
Down
Six Degrees Of Freedom

FIG. 33

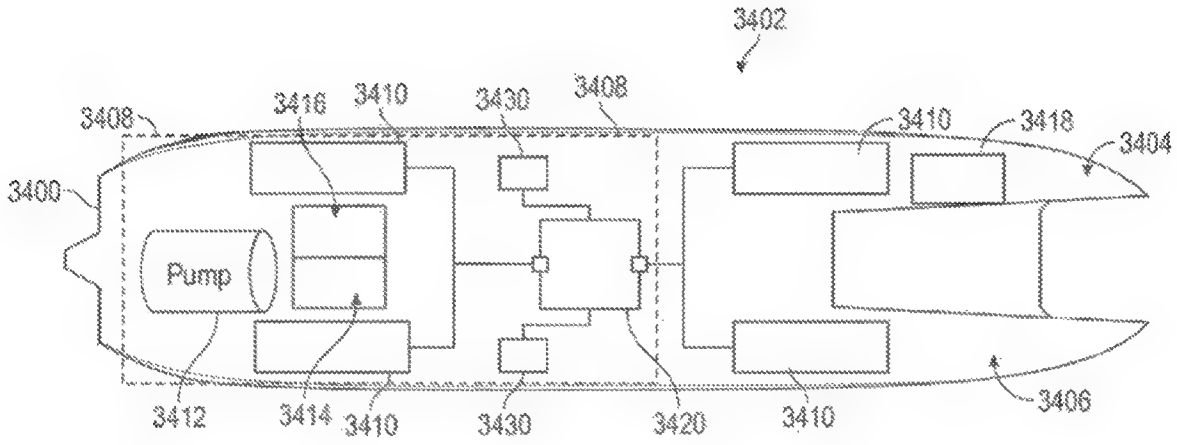
3402
3408
3416
3410
3430
3408
3410
3418
3404
3400
Pump
3412
3414
3410
3430
3420
3410
3406

FIG. 34

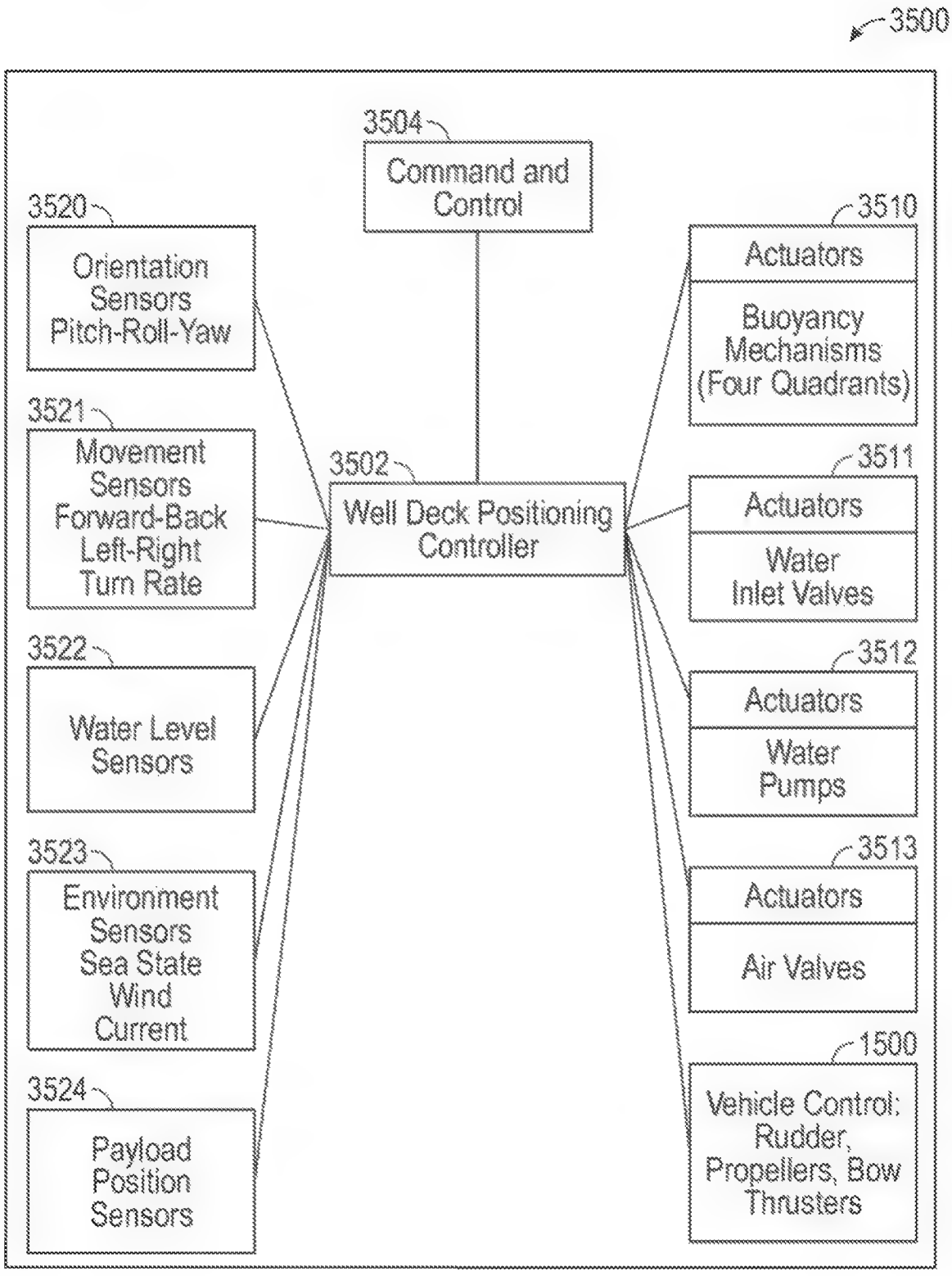
3500
3504
Command and Control
3520
Orientation Sensors Pitch-Roll-Yaw
3521
Movement Sensors Forward-Back Left-Right Turn Rate
3522
Water Level Sensors
3523
Environment Sensors Sea State Wind Current
3524
Payload Position Sensors
3502
Well Deck Positioning Controller
3510
Actuators
Buoyancy Mechanisms (Four Quadrants)
3511
Actuators
Water Inlet Valves
3512
Actuators
Water Pumps
3513
Actuators
Air Valves
1500
Vehicle Control: Rudder, Propellers, Bow Thrusters

FIG. 35

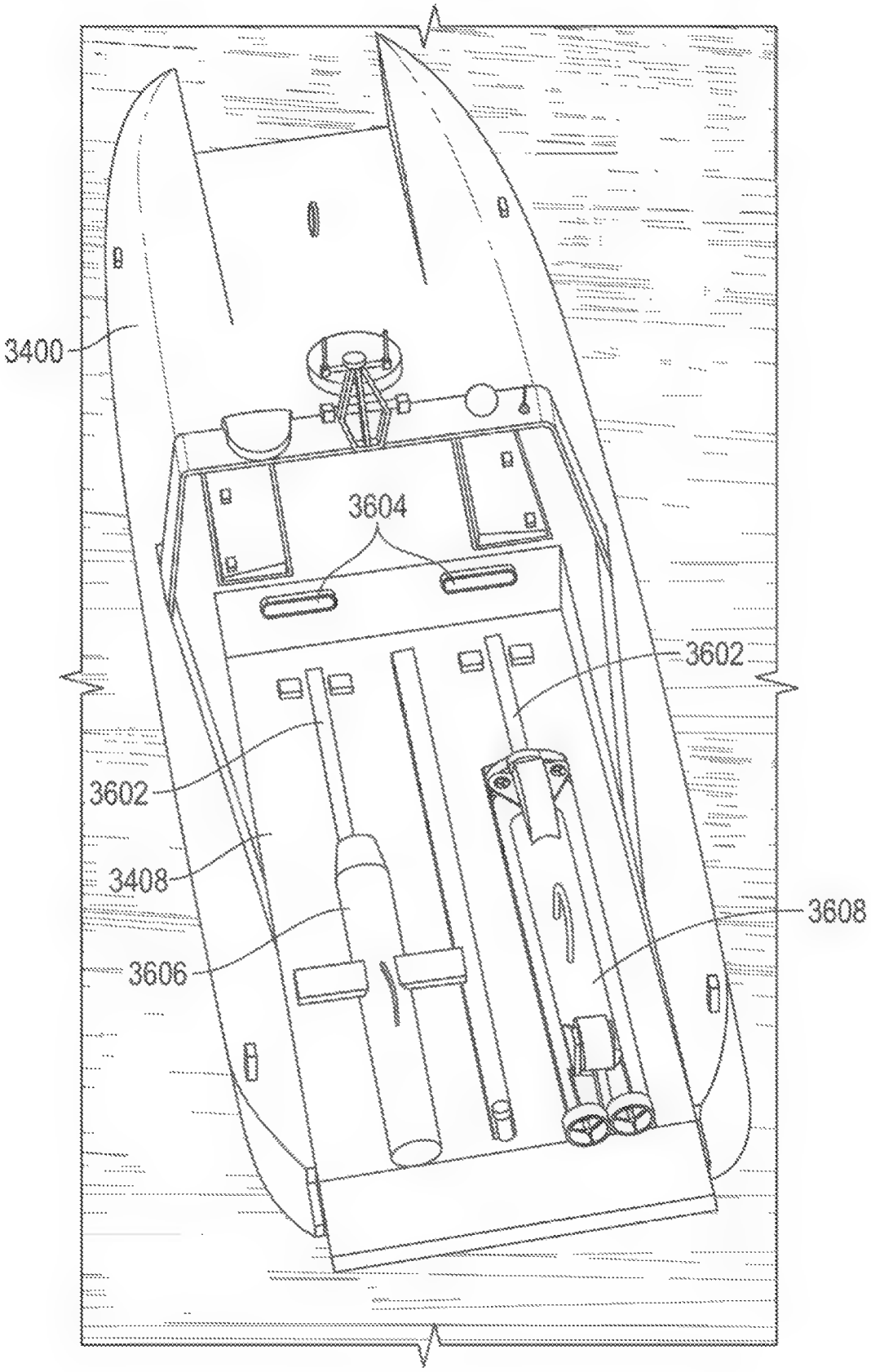

FIG. 36

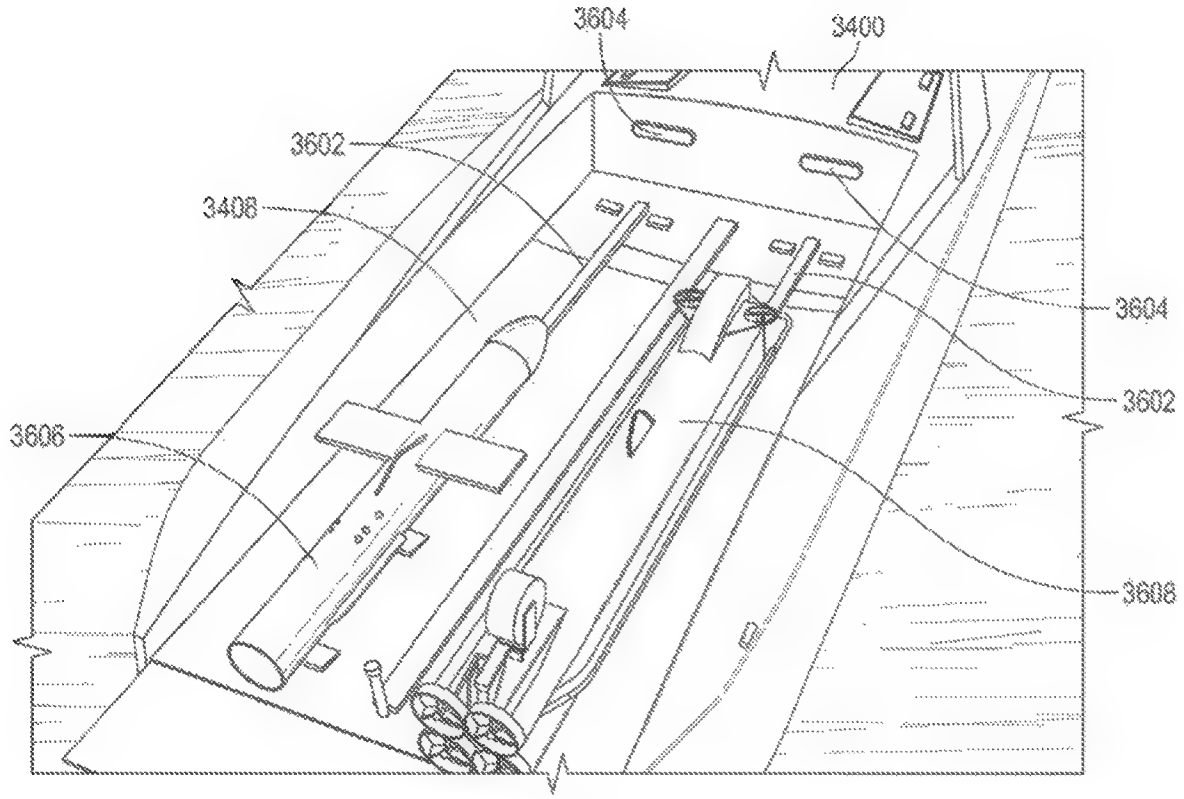

FIG. 37

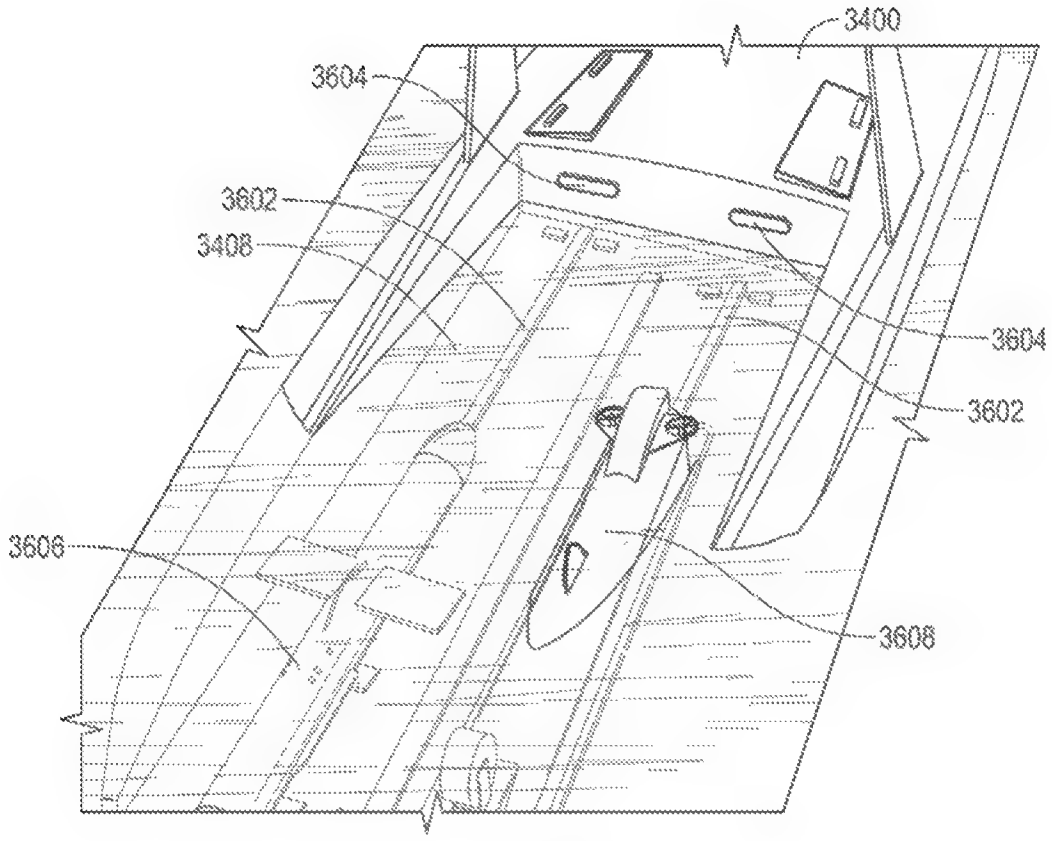

FIG. 38

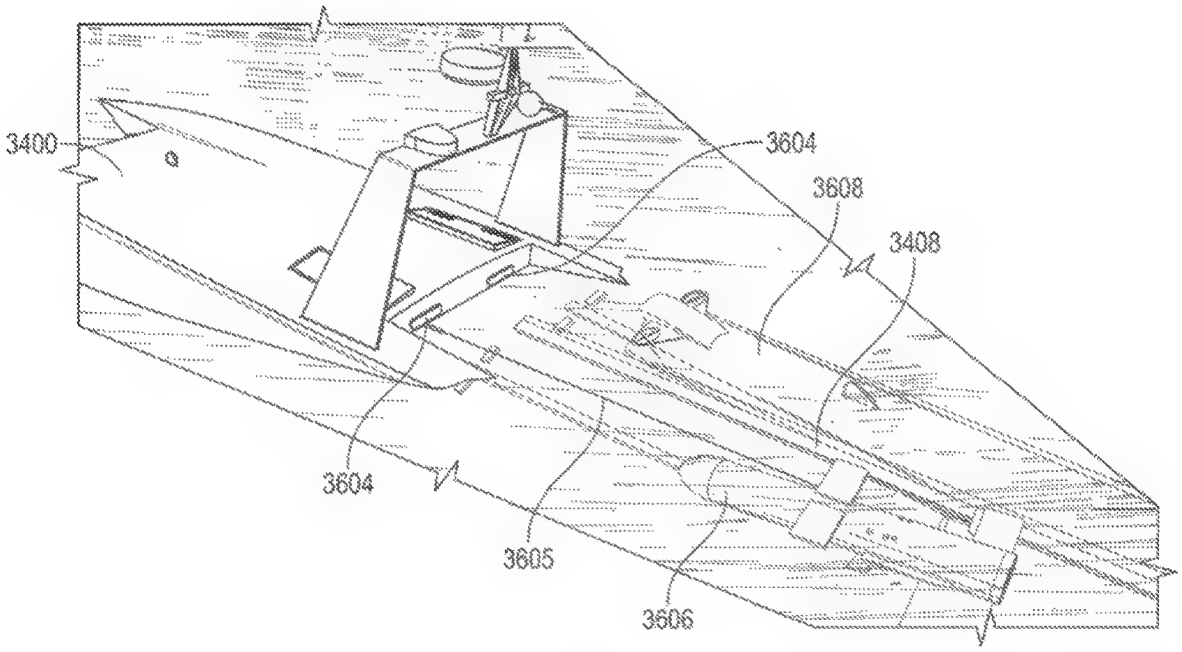

FIG. 39

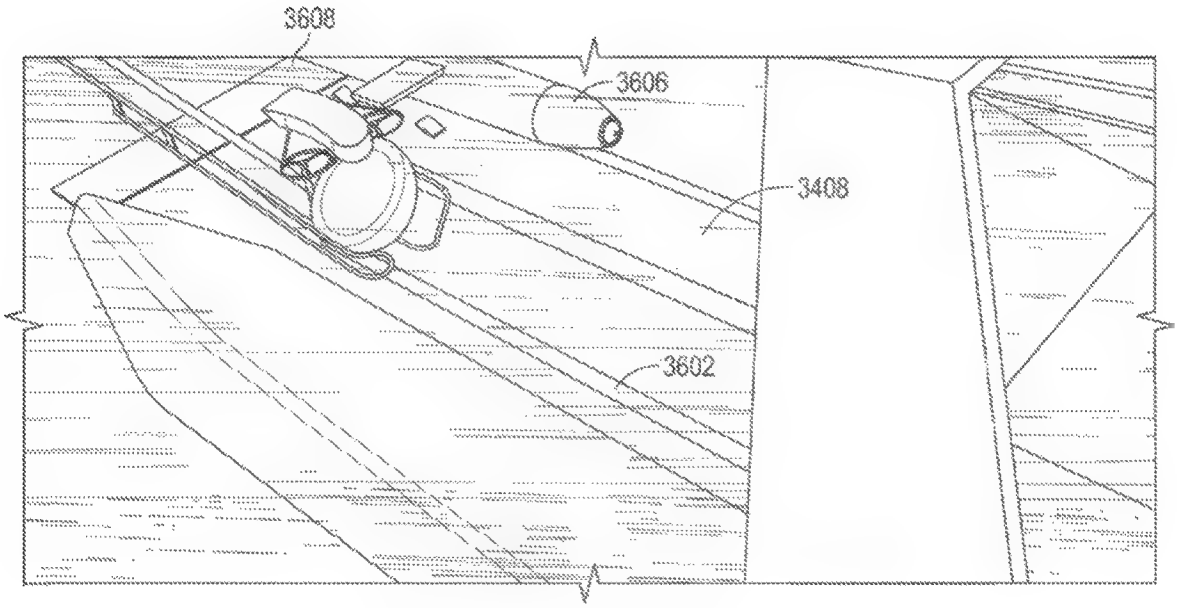

FIG. 40

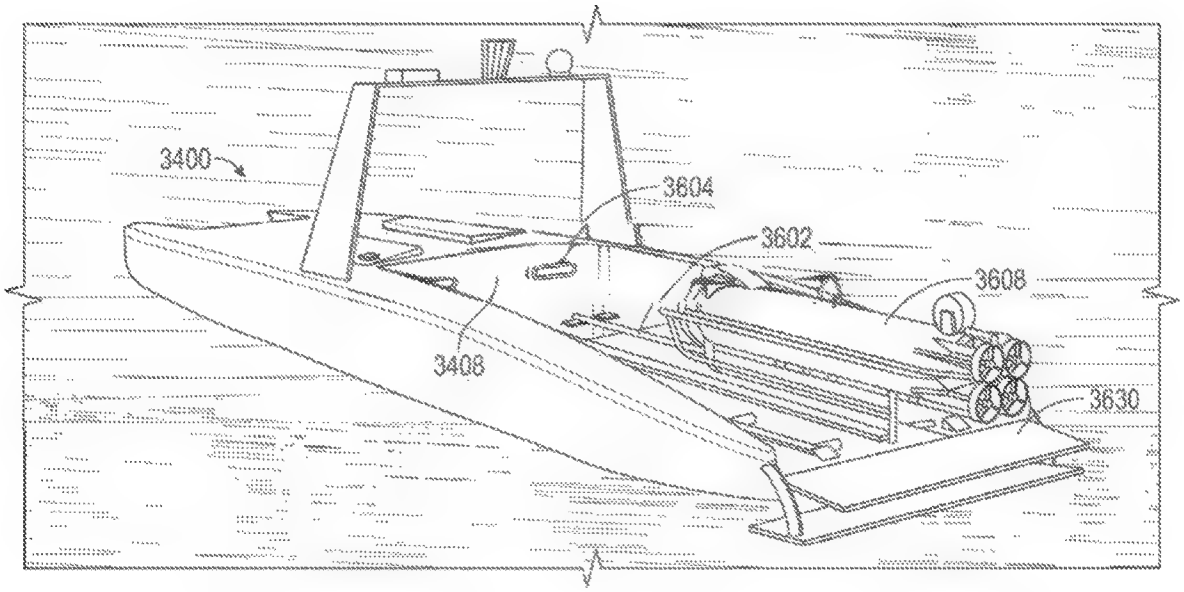

FIG. 41

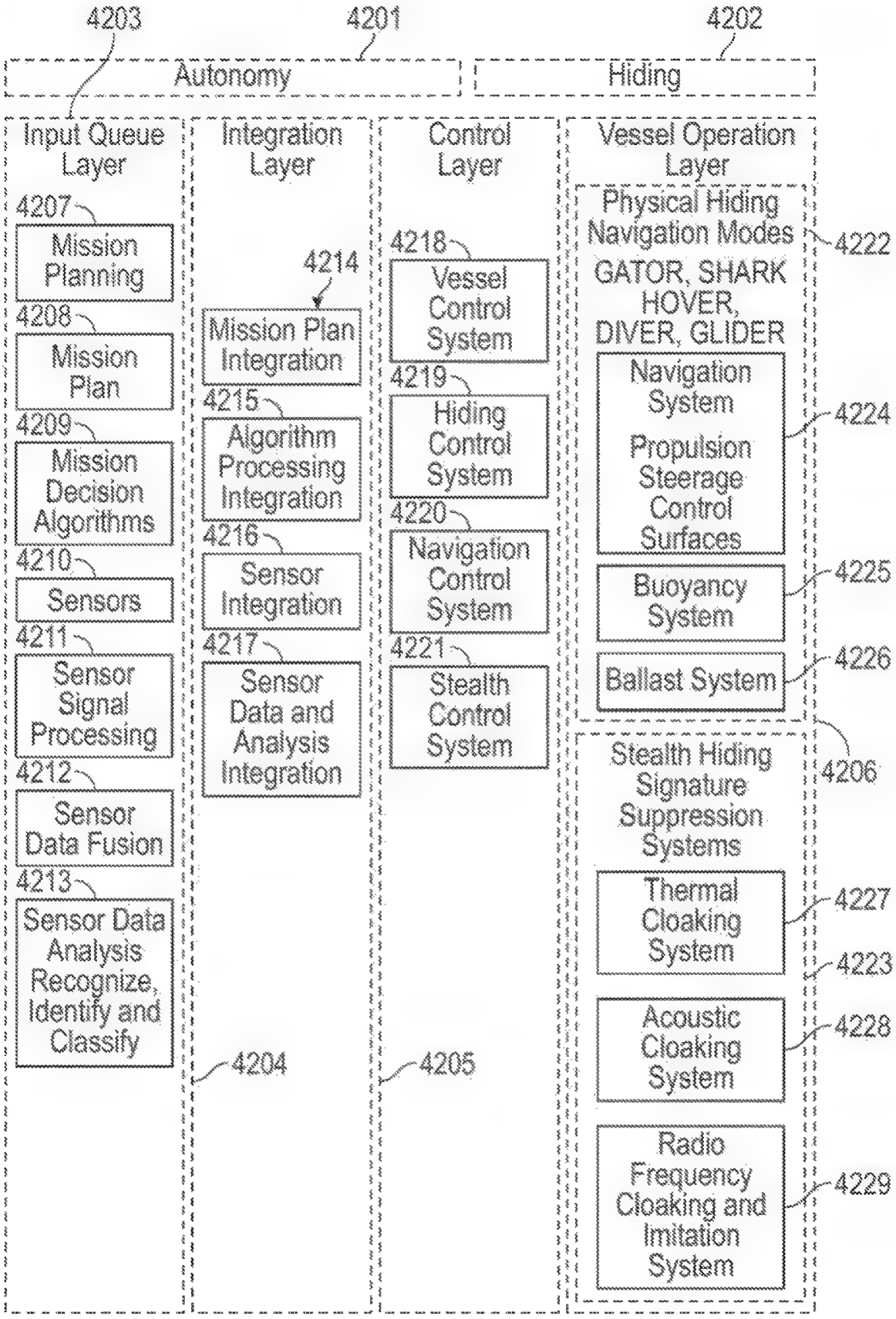
4203
4201
4202
Autonomy
Hiding
Input Queue Layer
Integration Layer
Control Layer
Vessel Operation Layer
4207
Mission Planning
4208
Mission Plan
4209
Mission Decision Algorithms
4210
Sensors
4211
Sensor Signal Processing
4212
Sensor Data Fusion
4213
Sensor Data Analysis Recognize, Identify and Classify
4214
Mission Plan Integration
4215
Algorithm Processing Integration
4216
Sensor Integration
4217
Sensor Data and Analysis Integration
4218
Vessel Control System
4219
Hiding Control System
4220
Navigation Control System
4221
Stealth Control System
Physical Hiding Navigation Modes
GATOR, SHARK HOVER, DIVER, GLIDER
4222
Navigation System
Propulsion
Steerage
Control Surfaces
4224
Buoyancy System
4225
Ballast System
4226
Stealth Hiding Signature Suppression Systems
4206
Thermal Cloaking System
4227
4223
Acoustic Cloaking System
4228
Radio Frequency Cloaking and Imitation System
4229
4204
4205

FIG. 42

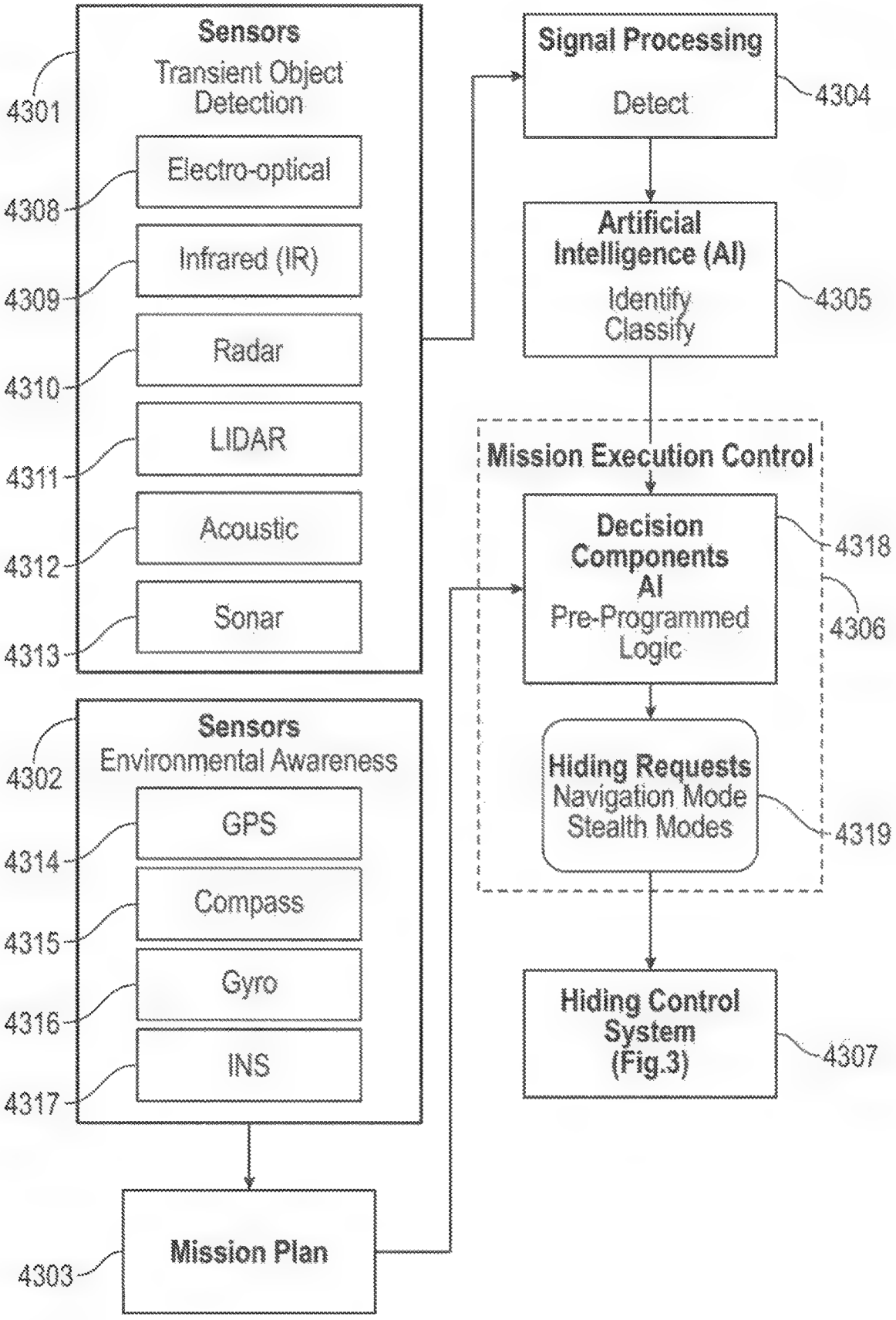
Sensors
Transient Object Detection
4301
Electro-optical
4308
Infrared (IR)
4309
Radar
4310
LIDAR
4311
Acoustic
4312
Sonar
4313
Sensors
Environmental Awareness
4302
GPS
4314
Compass
4315
Gyro
4316
INS
4317
Mission Plan
4303
Signal Processing
Detect
4304
Artificial Intelligence (AI)
Identify
Classify
4305
Mission Execution Control
Decision Components AI
Pre-Programmed Logic
4318
4306
Hiding Requests
Navigation Mode
Stealth Modes
4319
Hiding Control System
(Fig.3)
4307

FIG. 43

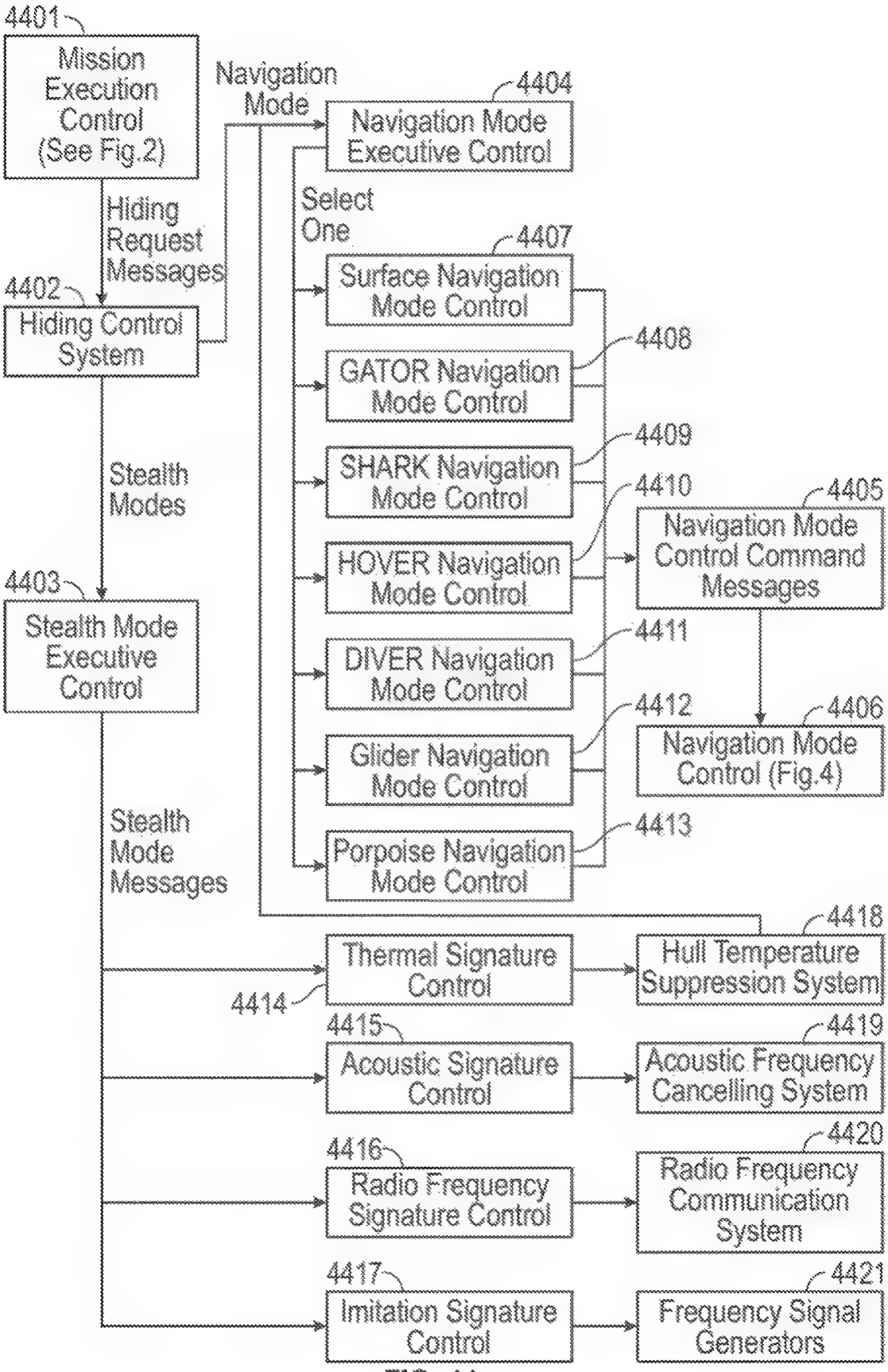
4401
Mission Execution Control (See Fig.2)
Navigation Mode
4404
Navigation Mode Executive Control
Hiding Request Messages
Select One
4407
Surface Navigation Mode Control
4402
Hiding Control System
4408
GATOR Navigation Mode Control
4409
SHARK Navigation Mode Control
Stealth Modes
4410
4405
Navigation Mode Control Command Messages
HOVER Navigation Mode Control
4403
Stealth Mode Executive Control
4411
DIVER Navigation Mode Control
4412
4406
Navigation Mode Control (Fig.4)
Glider Navigation Mode Control
Stealth Mode Messages
4413
Porpoise Navigation Mode Control
4418
Thermal Signature Control
Hull Temperature Suppression System
4414
4415
4419
Acoustic Signature Control
Acoustic Frequency Cancelling System
4420
4416
Radio Frequency Signature Control
Radio Frequency Communication System
4417
4421
Imitation Signature Control
Frequency Signal Generators

FIG. 44

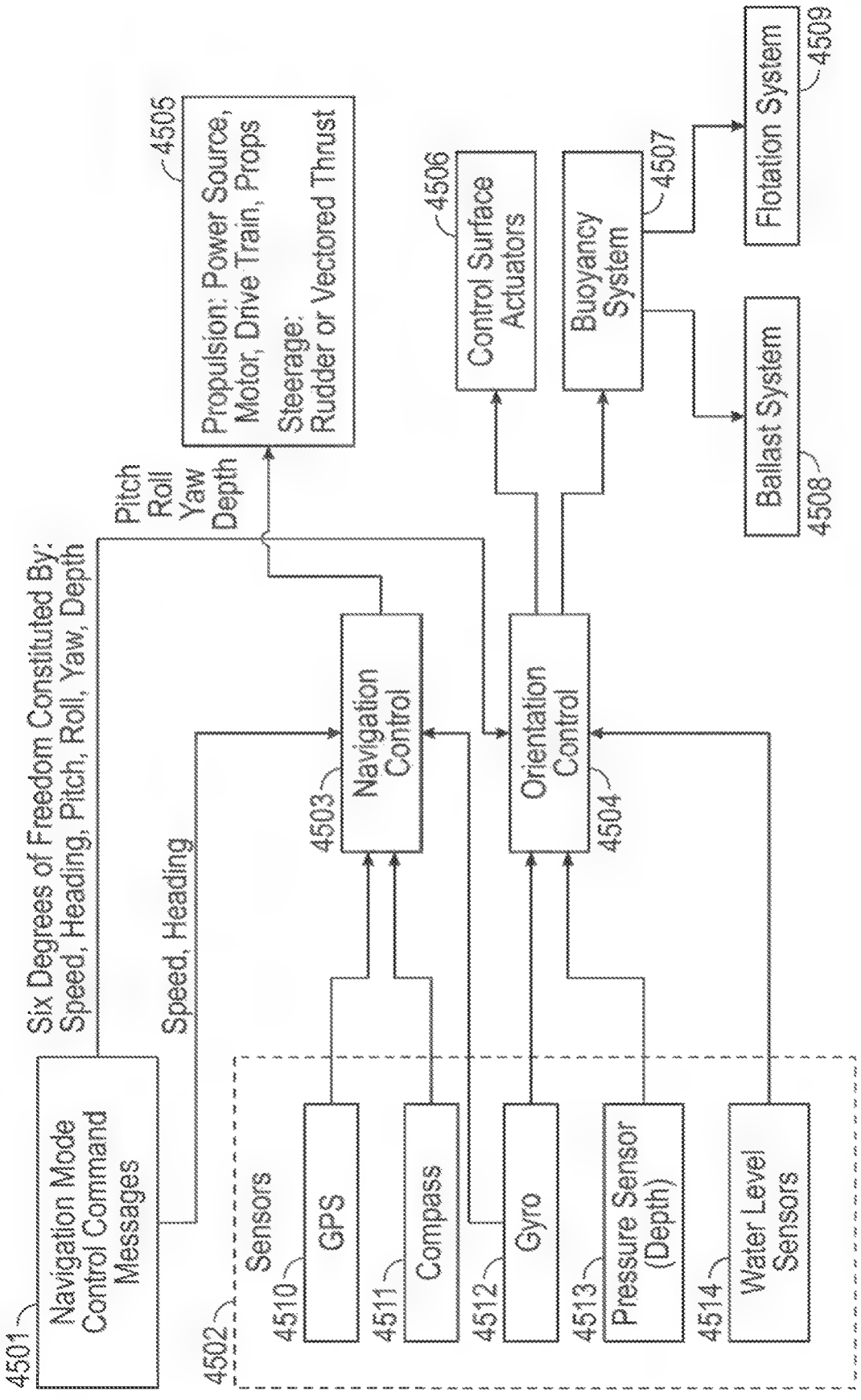
4501
Navigation Mode Control Command Messages
Six Degrees of Freedom Constituted By: Speed, Heading, Pitch, Roll, Yaw, Depth
Speed, Heading
4502
Sensors
4510
GPS
4511
Compass
4512
Gyro
4513
Pressure Sensor (Depth)
4514
Water Level Sensors
4503
Navigation Control
4504
Orientation Control
Pitch
Roll
Yaw
Depth
4505
Propulsion: Power Source, Motor, Drive Train, Props
Steerage: Rudder or Vectored Thrust
4506
Control Surface Actuators
4507
Buoyancy System
4508
Ballast System
4509
Flotation System

FIG. 45

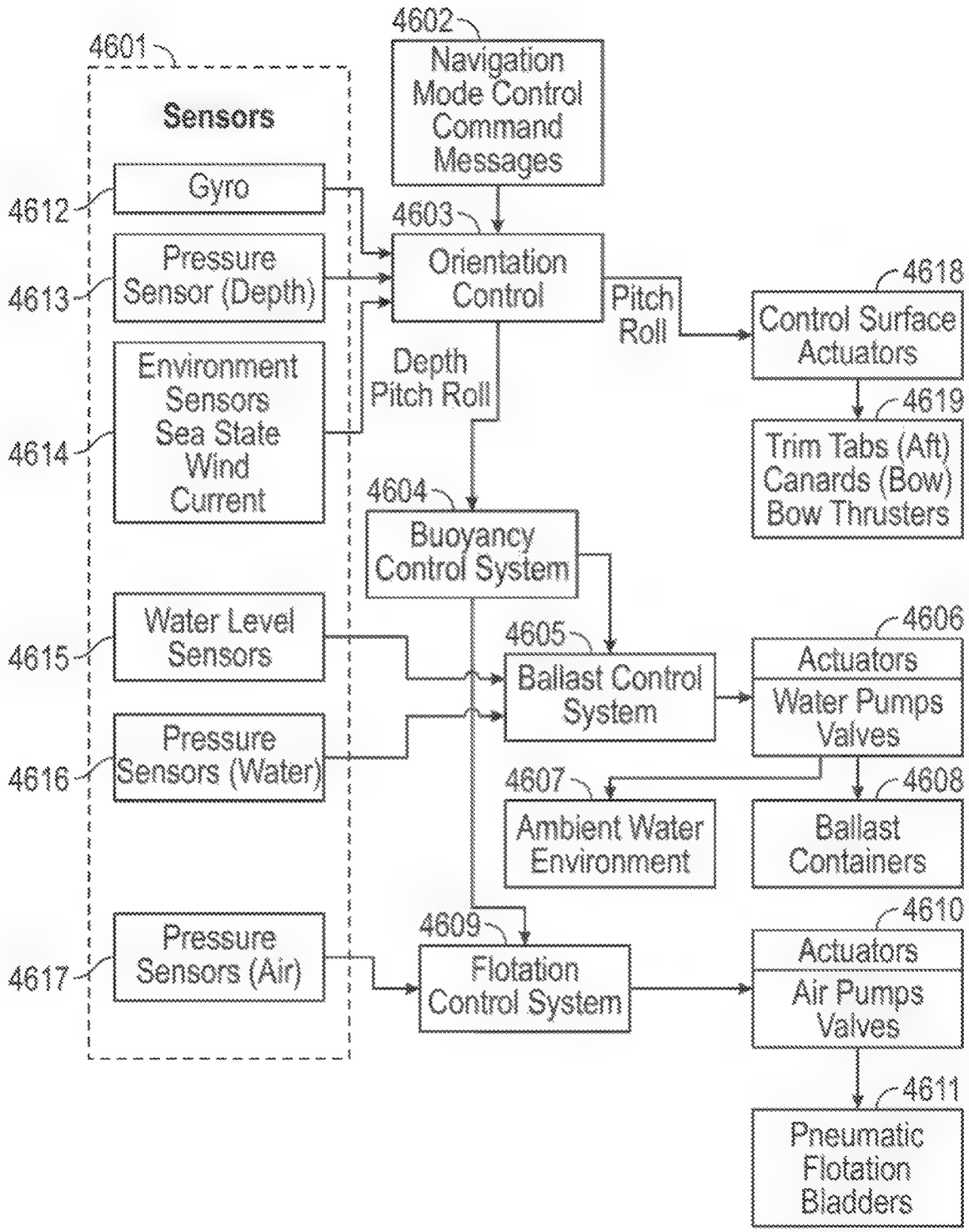
4601
Sensors
4612
Gyro
4613
Pressure Sensor (Depth)
4614
Environment Sensors Sea State Wind Current
4615
Water Level Sensors
4616
Pressure Sensors (Water)
4617
Pressure Sensors (Air)
4602
Navigation Mode Control Command Messages
4603
Orientation Control
Depth Pitch Roll
Pitch Roll
4604
Buoyancy Control System
4605
Ballast Control System
4607
Ambient Water Environment
4609
Flotation Control System
4618
Control Surface Actuators
4619
Trim Tabs (Aft) Canards (Bow) Bow Thrusters
4606
Actuators
Water Pumps Valves
4608
Ballast Containers
4610
Actuators
Air Pumps Valves
4611
Pneumatic Flotation Bladders

FIG. 46

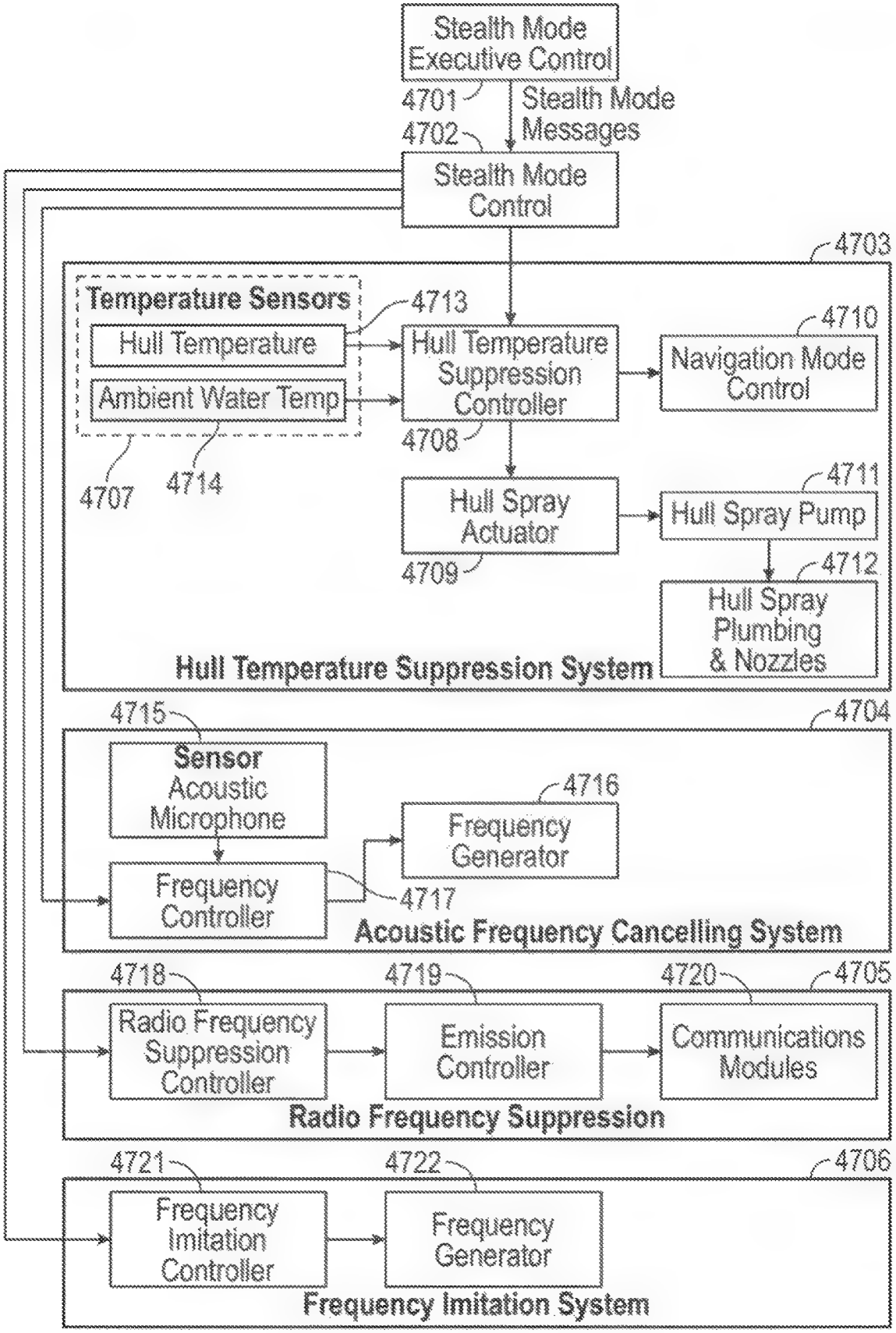
Stealth Mode Executive Control
4701
Stealth Mode Messages
4702
Stealth Mode Control
4703
Temperature Sensors
4713
Hull Temperature
Ambient Water Temp
Hull Temperature Suppression Controller
4710
Navigation Mode Control
4708
4707
4714
4711
Hull Spray Actuator
Hull Spray Pump
4709
4712
Hull Spray Plumbing & Nozzles
Hull Temperature Suppression System
4715
4704
Sensor Acoustic Microphone
4716
Frequency Generator
Frequency Controller
4717
Acoustic Frequency Cancelling System
4718
4719
4720
4705
Radio Frequency Suppression Controller
Emission Controller
Communications Modules
Radio Frequency Suppression
4721
4722
4706
Frequency Imitation Controller
Frequency Generator
Frequency Imitation System

FIG. 47

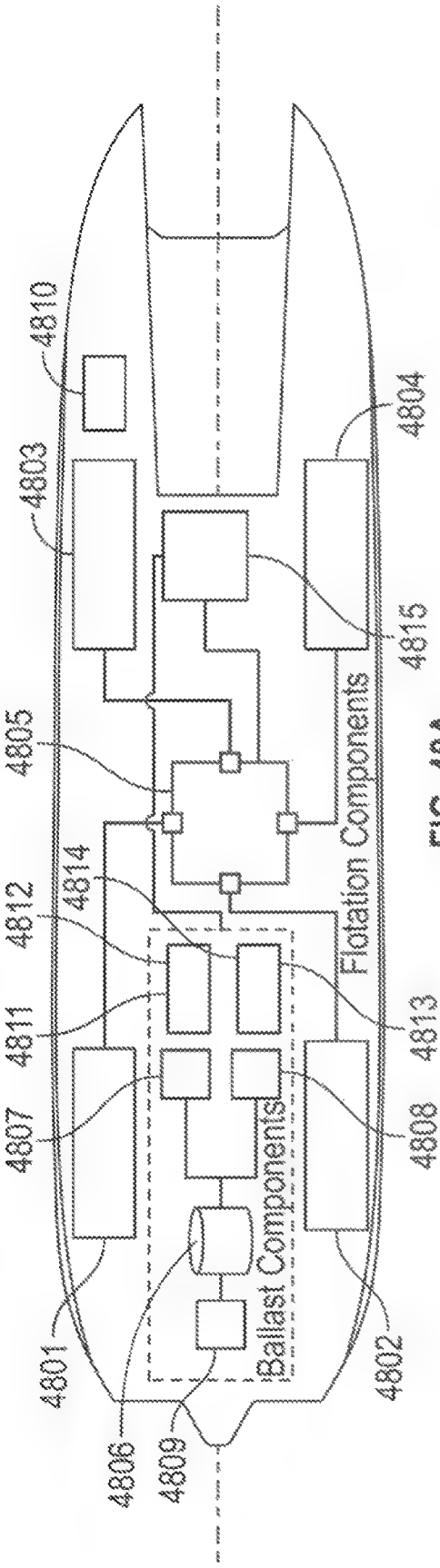

FIG. 48A

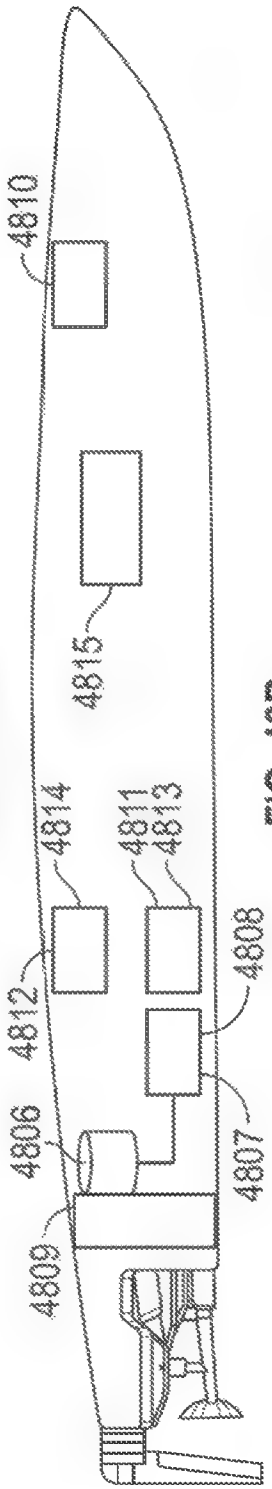

FIG. 48B

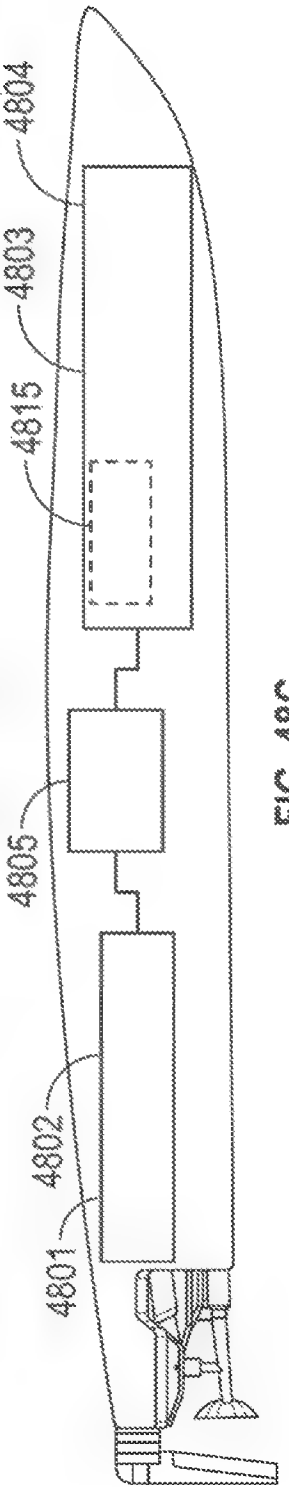

FIG. 48C

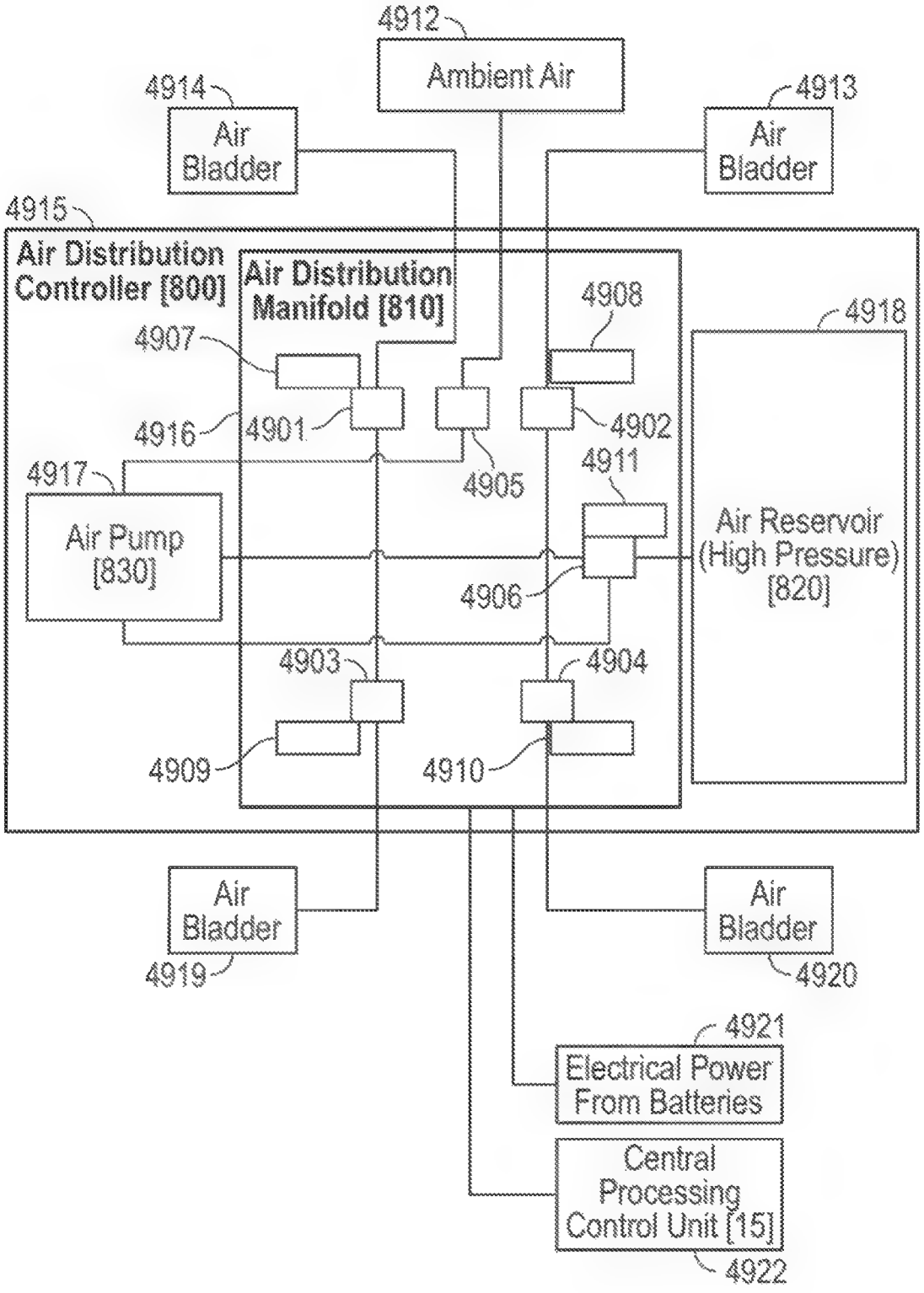
4912
Ambient Air
4914
Air Bladder
4913
Air Bladder
4915
Air Distribution Controller [800]
Air Distribution Manifold [810]
4908
4918
4907
4916
4901
4902
4905
4911
4917
Air Pump [830]
Air Reservoir (High Pressure) [820]
4906
4903
4904
4909
4910
Air Bladder
4919
Air Bladder
4920
4921
Electrical Power From Batteries
Central Processing Control Unit [15]
4922

FIG. 49

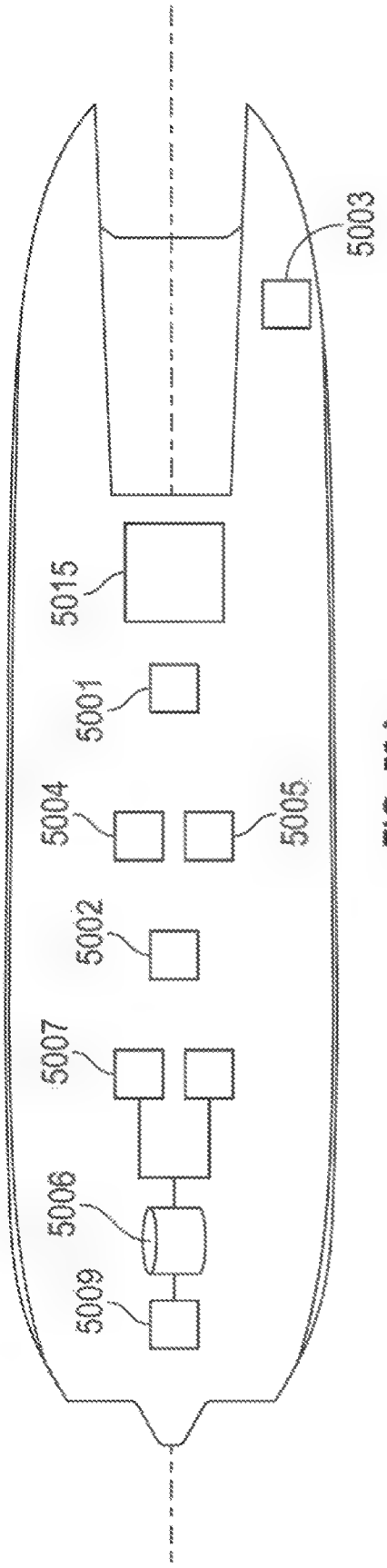

FIG. 50A

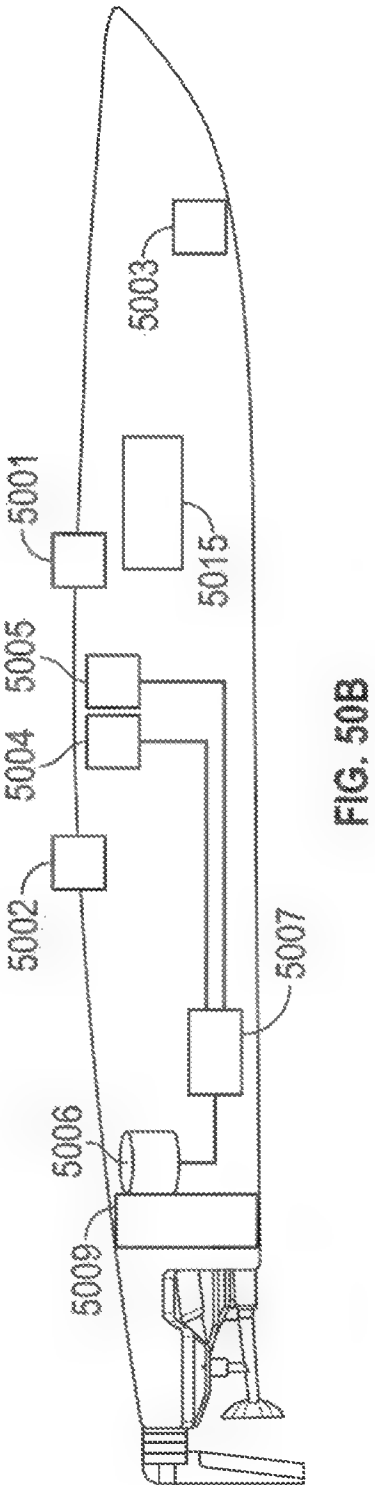

FIG. 50B

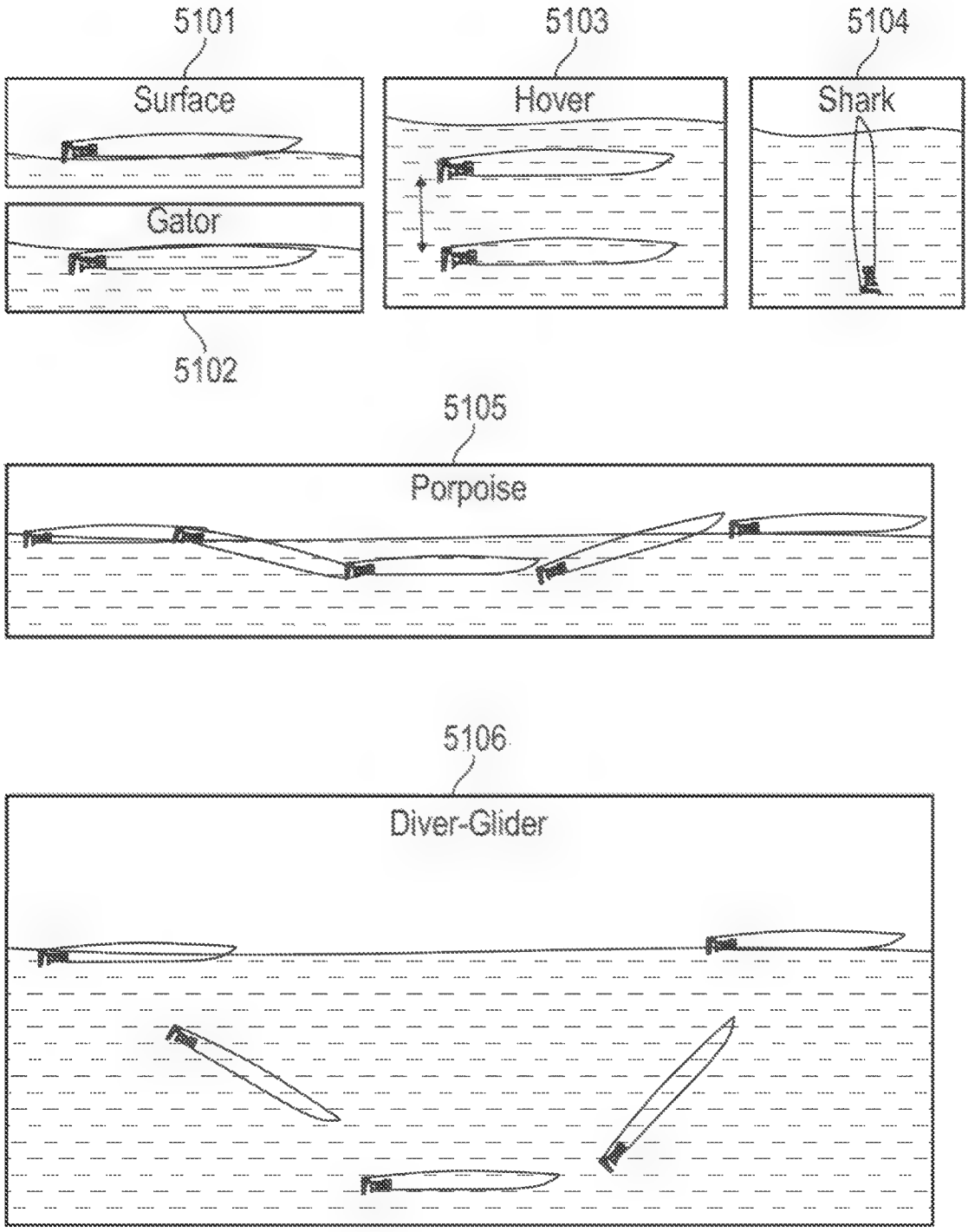
5101
Surface
Gator
5102
5103
Hover
5104
Shark
5105
Porpoise
5106
Diver-Glider

FIG. 51

SYSTEMS AND METHODS FOR AUTONOMOUS SELECTION AND OPERATION OF COMBINATIONS OF STEALTH AND PERFORMANCE CAPABILITIES OF A MULTI-MODE UNMANNED VEHICLE

RELATED APPLICATIONS

This application is a continuation application of and claim priority under 35 U.S.C. § 120 of U.S. patent application Ser. No. 17/164,129 filed on Feb. 1, 2021 and titled SYSTEMS AND METHODS FOR AUTONOMOUS SELECTION AND OPERATION OF COMBINATIONS OF STEALTH AND PERFORMANCE CAPABILITIES OF A MULTI-MODE UNMANNED VEHICLE, which in turn is a continuation application of and claims priority under 35 U.S.C. § 120 of U.S. patent application Ser. No. 16/449,824 filed on Jun. 24, 2019 and titled Systems and Methods for Semi-Submersible Launch and Recovery of Objects from Multi-Mode Unmanned Vehicle, which in turn is a continuation-in-part application of and claims priority under 35 U.S.C. § 120 of U.S. patent application Ser. No. 15/609,459, now U.S. Pat. No. 10,331,131, issued Jun. 25, 2019 filed on May 31, 2017 and titled Systems and Methods for Payload Integration and Control in a Multi-Mode Unmanned Vehicle, which in turn is a continuation-in-part application of and claims priority under 35 U.S.C. § 120 of U.S. patent application Ser. No. 14/788,231, now U.S. Pat. No. 9,669,904, issued Jun. 6, 2017 filed on Jun. 30, 2015 and titled Systems and Methods for Multi-Role Unmanned Vehicle Mission Planning and Control, which in turn is a continuation-in-part application of and claims priority under 35 U.S.C. § 120 of U.S. patent application Ser. No. 13/470,866, now U.S. Pat. No. 9,096,106, issued Aug. 4, 2015 filed on May 14, 2012 and titled Multi-Role Unmanned Vehicle System and Associated Methods. The contents of these applications are incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates generally to the field of unmanned, autonomous vehicles. In particular, the invention relates to systems and methods for advantageous employment of unmanned vehicles that are capable of operating in atmospheric, marine, and submarine environments, and that are equipped for semi-submersible launch and recovery of objects such as vessels, equipment and/or people.

BACKGROUND OF THE INVENTION

For decades, use of unmanned vehicles, such as unmanned aircraft systems (generally referred to as drones), has been increasing as delivery, sensor, and automation technologies mature. One advantage of unmanned vehicles is the ability to establish large areas of operation with a significantly reduced number of people than would be required for a manned enterprise. Another advantage is the ability to deploy unmanned systems into operational environments that are hostile or dangerous to human beings.

The United States military is increasing its use of unmanned vehicles by all service branches and in all theaters of operation. Current examples of planned uses of unmanned vehicles in marine and submarine environments are for mine and submarine detection, maritime interdiction missions, harbor security, and intelligence, surveillance and reconnaissance (ISR) missions. The commercial market also

is also experiencing increased use of unmanned vehicles. Current examples of such use include search and rescue, drug interdiction, remote launch and recovery of external payloads, autonomous environmental testing, oil spill collection and monitoring, weather monitoring, and real time tsunami data collection and monitoring. The scope of both military and civilian uses for unmanned vehicles is expected to continue to increase significantly in the coming decade.

Conventional unmanned vehicle designs typically are each limited in scope to a particular operating environment and/or beneficial task. In the marine and submarine environments, most current unmanned vehicle designs are based on retrofits of manned vehicle designs and, as result, incur operational and performance envelope limitations built into vehicles designed for carrying people, such as described in U.S. Pat. No. 7,789,723 to Dane et. al. Alternatively, systems designed specifically as unmanned vehicles, such as described in U.S. Pat. No. 6,807,921 to Huntsman, typically are configured to achieve particular characteristics that are conducive to accomplishing a task of interest, such as, for example, endurance or underwater performance. However, these designs typically preclude achievement of a broader range of unmanned vehicle characteristics (e.g., multi-environment, multi-task) for the sake of limited-environment, limited-task characteristics.

There is a need to autonomously launch and recover various payloads, including vessels (surface and underwater), equipment and people, to perform missions covertly. There is a need for the vessels to autonomously perform the designated mission while hiding from detection by people or objects that could prevent the vessel from successfully completing its mission.

This background information is provided to reveal information believed by the applicant to be of possible relevance to the present invention. No admission is necessarily intended, nor should be construed, that any of the preceding information constitutes prior art against the present invention.

SUMMARY OF THE INVENTION

With the above in mind, embodiments of the present invention are related to an unmanned vehicle including a vehicle body, a propulsion system, a maneuvering system, a vehicle control system, a rack, a sensor, and a power supply. The vehicle body may include a pair of sponsons that may be substantially parallel. The propulsion system and the maneuvering system may be carried by the vehicle body. The vehicle control system may also be carried by the vehicle body, and may be used to control the speed, orientation, and direction of the unmanned vehicle, which may be in combination with the propulsion system and the maneuvering system.

The rack may be carried by the vehicle body. The rack may include a retractable mount that may move between a down position and an up position. The sensor system may be carried by the rack and may include a plurality of transient object detection sensors that may sense transient objects in an environment of unmanned vehicle. The power supply may be carried by the vehicle body. The plurality of transient object detection sensors of the sensor system may include a sensor adapted to detect an item of interest and may provide an item of interest signal to the vehicle control system.

The vehicle control system may be used to receive the item of interest signal. The vehicle control system may identify an item of interest classification and may provide a classification signal. The classification signal may be deter-

mined by the item of interest classification and may be utilized by the propulsion system, maneuvering system, vehicle control system, or retractable mount, which may be to avoid physical, electrical, acoustic, or thermal detection of the unmanned vehicle by the item of interest.

The maneuvering system and/or the propulsion system may be used to position the unmanned vehicle in a location that may be calculated to prevent detection of the unmanned vehicle by the item of interest. The plurality of transient object detection sensors may include one or more electro-optical sensors, infrared sensors, radar sensors, lidar sensors, acoustic sensors, and/or sonar sensors. The plurality of transient object detection sensors may also include one or more other sensors to determine a location of the item of interest, a velocity of the item of interest, and/or a dimension of the item of interest.

The down position of the retractable mount may be defined as the rack being positioned abuttingly adjacent to the vehicle body. The up position of the retractable mount may be defined as the retractable mount being substantially latitudinally extended from the vehicle body. The item of interest classification may be an aquatic vessel, a human, a mine, an aerial vehicle, and/or a chemical. The unmanned vehicle may also include a stealth control system, a thermal cloaking system, an acoustic cloaking system, a radio frequency cloaking system, and/or a radio frequency imitation system. The classification signal may be utilized by the stealth control system to activate the thermal cloaking system, the acoustic cloaking system, the radio frequency cloaking system, and/or the radio frequency imitation system.

The thermal cloaking system may be adapted to decrease a temperature of the vehicle body. The thermal cloaking system may include a first temperature sensor that may be positioned to measure a hull temperature, and a second temperature sensor that may be positioned to measure an ambient temperature. A target threshold difference between the hull temperature and the ambient temperature may be determined. The vehicle control system may control the propulsion system, maneuvering system, and/or the vehicle control system, which may be to maintain an actual difference between the hull temperature and the ambient temperature less than the target threshold when the thermal cloaking system is activated.

The vehicle control system may control a water spray system that may be directed at the exposed hull surface to maintain an actual difference between the hull temperature and the ambient temperature less than the target threshold when the thermal cloaking system is activated. The acoustic cloaking system may be adapted to cancel an acoustic frequency emitted by the unmanned vehicle. The acoustic cloaking system may include an acoustic sensor that may be adapted to sense a detectable frequency, and a frequency generator that may be configured to output a canceling frequency that may be calculated to suppress the detectable frequency.

The radio frequency cloaking system may be adapted to alter a radio frequency emitted by the unmanned vehicle. The radio frequency cloaking system may also be adapted to alter the emitted radio frequency to suppress an emission of the radio frequency, change a bandwidth of the radio frequency, and/or change a duration of transmission of the radio frequency. The radio frequency imitation system may also be adapted to recreate a target radio frequency. The radio frequency imitation system may include a frequency library that may include a designation of a plurality of frequency generators and associated frequencies. The radio frequency limitation system may also include a frequency generator that may be configured to output a frequency that may be associated with one of the plurality of frequency generators.

BRIEF DESCRIPTION OF THE DRAWINGS

Some embodiments of the present invention are illustrated as an example and are not limited by the figures of the accompanying drawings, in which like references may indicate similar elements.

FIG. **1** is an exploded solid model view of an unmanned vehicle according to an embodiment of the present invention.

FIG. **2** is a top plan view and a side elevation view of an unmanned vehicle according to an embodiment of the present invention.

FIG. **2A** is a front elevation view of an unmanned vehicle according to an embodiment of the present invention.

FIG. **3** is a table illustrating air glide parameters of an unmanned vehicle according to an embodiment of the present invention compared to air glide parameters to two exemplary aircraft known in the art.

FIG. **4** is a schematic overview of a propulsion control system of an unmanned vehicle according to an embodiment of the present invention.

FIG. **5** is a schematic overview of a propulsion system of an unmanned vehicle according to an embodiment of the present invention suitable for marine and submarine use.

FIG. **6** is a side elevation view and a bottom plan view of a ballast system of an unmanned vehicle according to an embodiment of the present invention.

FIG. **7** is a side elevation view and a top plan view of an adjustable center of gravity system of an unmanned vehicle according to an embodiment of the present invention.

FIG. **8** is a side elevation view and a top plan view of a pressurization system of an unmanned vehicle according to an embodiment of the present invention.

FIG. **9** is a solid model perspective view of control surfaces of an unmanned vehicle according to an embodiment of the present invention.

FIG. **10** is a plurality of partial perspective views of control surfaces of an unmanned vehicle according to an embodiment of the present invention.

FIG. **11** is a side elevation view and a top plan view of a retractable device rack of an unmanned vehicle according to an embodiment of the present invention.

FIG. **12** is a front elevation view representing a retractable device rack of an unmanned vehicle according to an embodiment of the present invention showing the retractable device rack in an extended position.

FIG. **13** is an exploded perspective view of an interchangeable payload deck of an unmanned vehicle according to an embodiment of the present invention including a solar panel payload module.

FIG. **14** is a top plan view and a side elevation view of an interchangeable payload deck of an unmanned vehicle according to an embodiment of the present invention including a wind sail payload module.

FIG. **15** is a schematic overview of a multi-mode navigation control system of an unmanned vehicle according to an embodiment of the present invention.

FIG. **16** is a schematic overview of an on-board control system of an unmanned vehicle according to an embodiment of the present invention.

FIG. **17** is a schematic overview of an off-board control system of a mission planning and control system according to an embodiment of the present invention.

FIG. **18** is a schematic overview of a mission planning and control system according to an embodiment of the present invention.

FIG. **19** is a flowchart of a mission control operation for an unmanned vehicle according to an embodiment of the present invention.

FIG. **20** is a flowchart of a mission management operation for an unmanned vehicle according to an embodiment of the present invention.

FIG. **21** is a flowchart of a mission planning and execution lifecycle according to an embodiment of the present invention.

FIG. **22** is a schematic overview of an exemplary three-dimensional coverage grid for a mission planning and control system according to an embodiment of the present invention.

FIG. **23** is a block diagram representation of a machine in the example form of a computer system according to an embodiment of the present invention.

FIG. **24** is a bottom plan view of an unmanned vehicle according to an embodiment of the present invention.

FIG. **25** is a side elevation view of an unmanned vehicle according to an embodiment of the present invention.

FIG. **26**A is a front elevation view of an unmanned vehicle according to an embodiment of the present invention.

FIG. **26**B is a rear elevation view of an unmanned vehicle according to an embodiment of the present invention.

FIG. **27** is a top plan view of an unmanned vehicle according to an embodiment of the present invention.

FIG. **28**A is a side elevation view of an unmanned vehicle according to an embodiment of the present invention.

FIG. **28**B is a front elevation view of an unmanned vehicle according to an embodiment of the present invention.

FIG. **29** is a schematic overview of a payload control system according to an embodiment of the present invention.

FIG. **30** is a schematic overview of a payload control system according to an embodiment of the present invention.

FIG. **31** is a schematic diagram of exemplary payload signal and power interfaces according to an embodiment of the present invention.

FIG. **32** is a schematic diagram of exemplary payload mechanical interfaces according to an embodiment of the present invention.

FIG. **33** is a schematic diagram illustrating the six degrees of freedom related to the operation of an unmanned vehicle according to embodiments of the present invention.

FIG. **34** is a schematic diagram illustrating the layout of a buoyancy control system for an unmanned vehicle according to an embodiment of the present invention.

FIG. **35** is a schematic block diagram illustrating components defining a well deck position control system for an unmanned vehicle according to an embodiment of the present invention.

FIG. **36** is a top view illustrating a semi-submersible launch and recovery unmanned vehicle according to an embodiment of the present invention.

FIG. **37** is a perspective rear view illustrating the semi-submersible launch and recovery unmanned vehicle of FIG. **36** on the surface of the water.

FIG. **38** is a perspective rear view illustrating the semi-submersible launch and recovery unmanned vehicle of FIG. **36** partially submerged below the surface of the water.

FIG. **39** is a perspective rear view illustrating the semi-submersible launch and recovery unmanned vehicle of FIG. **36** during launch and recovery of a payload object.

FIG. **40** is a more detailed rear view illustrating the semi-submersible launch and recovery unmanned vehicle of FIG. **36** during launch and recovery of a payload object.

FIG. **41** is a perspective rear view illustrating the semi-submersible launch and recovery unmanned vehicle of FIG. **36** on the surface of the water after recovery of a payload object and back on the surface of the water.

FIG. **42** is a block diagram of an autonomous hiding system.

FIG. **43** is a flowchart depicting autonomous hiding decision logic.

FIG. **44** is a flowchart depicting hiding control system logic.

FIG. **45** is a flowchart depicting navigation control system logic.

FIG. **46** is a flowchart depicting orientation control system logic.

FIG. **47** is a flowchart depicting stealth control logic.

FIG. **48***a* is a top plan view of a schematic diagram depicting the physical layout of buoyancy control components according to an embodiment of the invention.

FIG. **48***b* is a side elevation view of ballast components of FIG. **48***a*.

FIG. **48***c* is a side elevation view of floatation components of FIG. **48***a*.

FIG. **49** is a block diagram of an air distribution controller.

FIG. **50***a* is a top plan view of a schematic diagram depicting the physical layout of thermal signature suppression components according to an embodiment of the invention.

FIG. **50***b* is a side elevation view of the thermal signature suppression components of FIG. **50***a*.

FIG. **51** is a schematic depiction of the orientation of the vessel in various navigation modes.

DETAILED DESCRIPTION OF THE INVENTION

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Those of ordinary skill in the art realize that the following descriptions of the embodiments of the present invention are illustrative and are not intended to be limiting in any way. Other embodiments of the present invention will readily suggest themselves to such skilled persons having the benefit of this disclosure. Like numbers refer to like elements throughout.

In this detailed description of the present invention, a person skilled in the art should note that directional terms, such as "above," "below," "upper," "lower," and other like terms are used for the convenience of the reader in reference to the drawings. Also, a person skilled in the art should notice this description may contain other terminology to convey position, orientation, and direction without departing from the principles of the present invention.

As a matter of definition, "mission," as used herein, refers to an overarching goal to be achieved through some combination of human, machine, material, and machine assets. "Planning," as used herein, refers to establishing a hierarchy of logistical and operational tasks to be accomplished using available mission assets, and to be assigned and managed at the appropriate level of abstraction. For example, and without limitation, levels of abstraction for asset assignment may include an individual unmanned vehicle being assigned a specific task, an unmanned vehicle sub-group being responsible for a mission sub-goal, and/or a full set of available assets being dedicated to an overall mission goal. Therefore, planning may involve pre-configuring missions for each unmanned vehicle as well as mapping and visualizing groups of unmanned vehicles. "Control," as used herein, refers to asset tracking, data collection, and mission adjustments accomplished in real-time as execution of a plan unfolds and as a mission evolves. Control, in the context of unmanned vehicle use, may involve selection of deployment modes (for example, and without limitation, air, marine, and submarine) and operational timing (for example and without limitation, active, wait at location, and remain on standby).

The furtherance of the state of the art described herein is based on advantageous employment of the multi-mode capabilities of the multi-mode unmanned vehicle disclosed in U.S. patent application Ser. No. 13/470,866 by Hanson et al., which is incorporated in its entirety herein by reference. The mission planning and control system described herein applies at least in part to the transit routes of one or more unmanned vehicles, each of which may be capable of air glide, water surface (e.g. marine), and sub-surface (e.g., submarine) modes of operation. For example, and without limitation, a single unmanned vehicle may transit across multiple modes of operation within a single transit route, and the respective transit routes of multiple unmanned vehicles across air mode, water surface mode, and sub-surface mode may be coordinated by the mission planning and control system.

Mission planning and control, as used herein, involves addressing the problem of accomplishing missions by efficiently and effectively employing some number of unmanned vehicles, each capable of multi-mode operation, and all coordinated in their actions both temporally and geographically. A significant portion of mission planning and control involves coordination across large time spans and diverse global locations. For example, and without limitation, such coordination may involve off-board command and control systems that may communicate and may integrate with unmanned vehicle on-board systems. Also for example, and without limitation, unmanned vehicles may coordinate with each other, often in sub-groups, as well as coordinate with other assets.

Referring now to FIGS. **1**, **2**, and **2**A, an unmanned vehicle **100** capable of operating in the air, on the surface of the water, and underwater according to an embodiment of the present invention will now be discussed. Throughout this disclosure, the unmanned vehicle **100** may also be referred to as a vehicle, an autonomous vehicle, a vessel, or the invention. Alternate references of the unmanned vehicle **100** in this disclosure are not meant to be limiting in any way.

The unmanned vehicle **100** according to an embodiment of the present invention may include a vehicle body **105** which may be configured as an aerohydrodynamic wing, which will now be described in greater detail. The vehicle body **105** according to an embodiment of the present invention may exhibit the shape characteristics of a catamaran including two opposing and substantially-parallel sponsons **200** each having a stepped hull **210**. The stepped hull design may advantageously increase the efficiency of the unmanned vehicle **100** by providing lower drag and increased stability at speed. The stepped hull **210** may also enhance maneuverability of the unmanned vehicle **100**. Referring now additionally to FIG. **2**A, the catamaran-style stepped hull **210** additionally may have shape characteristics that provide aerodynamic stability and control in the form of a central tunnel portion **250** and a central wing-shaped portion **220** of the vehicle body **105**. The wing **220** may be characterized by a leading edge **221**, a trailing edge **223**, a port edge **226**, a starboard edge **228**, an upper surface **222**, and a lower surface **224**. The two sponsons **200** may be coupled to the port **226** and starboard **228** edges of the wing **220**, respectively. Each sponson **200** may be characterized by a proximal wall **240** positioned adjacent the centrally-positioned wing **220** and a distal wall **260** positioned opposite the proximal wall **240**. The two proximal walls **240** of the sponsons **200** and the lower surface **224** of the wing **220** may define a tunnel **250** through which fluid (for example, and without limitation, water and/or air) may pass when the vehicle **100** is in motion relative to the fluid. The central wing-shaped portion **220** of the vehicle body **105** may have varying widths according to the mission-driven aerodynamic and hydrodynamic characteristics of the unmanned vehicle **100**.

Continuing to refer to FIGS. **1**, **2** and **2**A, aerodynamics of the unmanned vehicle **100** are now discussed in more detail. More specifically, the unmanned vehicle body **105** may be shaped such that opposing lift forces may be balanced. For example, top of vehicle **222** lift may be caused by decreased air pressure resulting from increased air velocity, while opposing rear of vehicle lift may be caused by increased air pressure resulting from decreased air velocity. An increase in angle of attack may cause increased vertical lift on the lower surface **224** of the wing defining the tunnel **250**, which may result in an upward force forward of the centerline. An increased angle of attack may also cause air flow to slow and pressure to increase under the tunnel **250**, which may result in increased lift with a force vector aft of the centerline. The top and rear lift vectors may result in a balanced lift rather than rotational forces, so that the vehicle body **105** may move in a controlled fashion along its central axis. The constrained air tunnel **250** with canards and trim tabs (described below) at the points where air enters (e.g., leading edge **221**) and exits (e.g., trailing edge **223**) may enable good control of air flow about the vehicle **100** and resulting lift

FIG. **3** summarizes wind tunnel test results **300** for an unmanned vehicle **100** characterized by the aerohydrodynamic wing design disclosed above. As illustrated in FIG. **3**, the unmanned vehicle body **105** may achieve a lift to drag (L/D) ratio **320** of 4.6 to 5.0 depending on angle of attack, tunnel **250** width, and sponson **200** depth. Test conditions predicted a minimum air speed **350** before stall of 65 knots for the unmanned vehicle **100** at a maximum angle of attack, and good horizontal glide control at 135 knots (horizontal landing speed **340**). Sample field results included stable laminar air flow at 225 knots and balanced forces (L/Weight, D/Thrust) at 165 knots. Demonstration of an 80 foot drop of the unmanned vehicle **100** resulted in a measured maximum air speed of 55 knots and an angle of attack of 25 degrees.

Continuing to refer to FIG. **3**, the aerodynamic characteristics of the unmanned vehicle **100** are now discussed in more detail by comparison to a NASA orbiter (e.g. Space

Shuttle) **310**. In one exemplary embodiment, the present invention may exhibit the following dimensions:

Weight: 86 pounds
Length: 95 inches (7.92 feet)
Tunnel (wing) length: 90 inches (7.5 feet)
Tunnel (wing) width: 11 inches
Height: 12.5 inches
Total area under tunnel=6.88 square feet
Weight per wing area=12.5 pounds per square foot

For purposes of comparison **310**, a representative implementation of the NASA orbiter is known to exhibit the following dimensions:

Weight: 172,000 pounds
Length: 122 feet
Wing span: 78 feet
Height: 59 feet
Wing area=5380 square feet
Weight per wing area=32 pounds per square foot

As shown in FIG. **3**, the present invention comparatively may have a slightly better L/D ratio on approach than the Space Shuttle Orbiter or, also for example, than the Concorde Supersonic Transport (SST). Moreover, the wing surface area to weight ratio **330** on the unmanned vehicle disclosed herein is more than twice as good in terms of wing loading as the ratio achieved by either the Concorde SST or the Space Shuttle Orbiter.

Those skilled in the art will recognize that the aerodynamic characteristics of the unmanned vehicle **100** operated in air mode will differ from the hydrodynamic characteristics of the same unmanned vehicle **100** operated in submarine mode. For example, and without limitation, underwater glide dynamics may differ from air glide dynamics in that water is an incompressible fluid and, therefore, lift/drag characteristics may be different when the unmanned vehicle **100** moves through water. In this regard, glide characteristics underwater may be dominated by drag characteristics as balanced across the surface area of the vehicle body **105**, the glide ratio, and the efficiency of changing from positive to negative buoyancy. For example, and without limitation, the unmanned vehicle **100** may be configured for sub-surface operation that may include underwater glide that employs ballast-only motivation, powered thrust, or power-augmented (e.g., ballast and powered thrust).

Those skilled in the art will appreciate that the hull **210** of the unmanned vehicle **100** does not necessarily have to be a stepped hull but, instead, can have any other shape. More specifically, it is contemplated that the hull **210** of the unmanned vehicle **100** may be smooth, for example, or may have any other shape while still achieving the goals, features and objectives according to the various embodiments of the present invention.

Referring now back to FIG. **1**, the vehicle body **105** of the unmanned vehicle **100** may carry a plurality of compartments to house propulsion and power components **110**, electrical and control components **120**, center of gravity adjustment actuators **130**, ballast components **140**, and internally stowed payloads **150**. These compartments may be sealed from each other by partitions **160** integrated into the vehicle body **105** with sealed electrical and mechanical interconnections **170**. All vehicle compartments are preferably sealed from the external environment by hatches **180** with pressure seals **190** designed for both submarine and atmospheric environments. The plurality of sealed compartments can be pressurized to advantageously allow for deeper submerged (e.g., submarine) operation, and may be designed to maintain sealed integrity to a submerged depth in excess of one hundred (100) feet. Those skilled in the art will appreciate that each of the above-mentioned components do not necessarily need to be positioned in separate compartments. The unmanned vehicle **100** according to an embodiment of the present invention does contemplate that the various components may be organized in combined compartments, in one single compartment, in a combination of compartments, or in any other configuration. For example, and without limitation, the plurality of sealed compartments may define an on-board environment inside one or more of the sealed compartments, and an external environment outside one or more of the sealed compartments.

The present invention may include a sensor system to collect both vehicle **100** functional systems data and also external environmental data. The sensor system may comprise a variable set of sensors of many kinds that collect a wide variety of data from disparate sources, an electronic communication network over which the sensors may send data, and a data processing and routing system for collected sensor data. In one embodiment of the present invention, data representing the condition of components in the on-board environment may be collected by functional sensors such as the following: Global Position System (GPS), electronic compass, accelerometers, roll, pitch, yaw orientation, depth, pressure, temperature, voltage, drive train revolutions per minute (RPM), vibration at multiple locations, vehicle humidity, fuel level, and charge level. External environmental data may be collected by sensors that may include a video camera with computer-controlled articulation, zoom and night vision; electro-optical/infrared imaging and an audio sensor. Optional sensors may include, but are not limited to, radar, sonar, chemical and radiation sensors. External sensors may be mounted on a retractable device rack, as described below. Sensor signals may be connected to a signal multiplexing unit that may provide signal conditioning and routing, and the multiplexing component may be connected to a sensor data processing subsystem that includes a computer software component that may be located in the vehicle's **100** central computer. The sensor system also may include a sensor data storage system comprised of digital storage components that may allow for real time data collection and for latent data processing. The system may categorize stored data by a number of attributes that may include time of capture, device, and data type.

Still referring to FIGS. **1**, **2**, and **2**A, the vehicle body **105** may scale proportionally in three dimensions. The vehicle body **105** according to an embodiment of the present invention may advantageously have a length scaling from about 2 feet to 70 feet, a beam from about 10 inches to 15 feet, and a depth of about 4 inches to 5 feet. The vehicle body **105** according to an embodiment of the present invention can advantageously range in weight from about 5 pounds to 15,000 pounds. Alternate references of the vehicle body **105** in this disclosure are not meant to be limiting in any way. More particularly, any reference to dimensions above is meant for exemplary purposes, and not meant to be limiting in any way.

The vehicle body **105** may be constructed of various materials, including fiberglass, carbon fiber, or aramid fiber, depending on the relative importance of prevailing design factors. For example, and without limitation, if lowering construction costs of the unmanned vehicle **100** is an important design factor, the choice of fiberglass as the material for the vehicle body **105** may reduce the total cost to manufacture the unmanned vehicle **100**. In another example and without limitation, if an important design factor is enhancing strength to weight characteristics in the vehicle body **105** for the unmanned vehicle **100** to withstand ambient air pres-

sures during aerodynamic flight or glide as well as to withstand ambient water pressures when submerged in water to hundreds of feet, the choice of aramid fiber as the construction material for the vehicle body **105** may be desirable. Those skilled in the art will appreciate, however, that the unmanned vehicle **100** according to an embodiment of the present invention may be constructed of any material, and that the materials mentioned above are exemplary in nature, and not meant to be limiting. According to an embodiment of the present invention, a vehicle body **105** constructed of disclosed materials less than 0.125 inches thick may exhibit a high tensile strength to counter the pressures at hundreds of feet under water as well as to support a controllable low pressure differential across the exterior of the vehicle body **105** during atmospheric flight.

Referring now to FIG. **4**, a propulsion system **400** of the unmanned vehicle **100** according to an embodiment of the present invention will now be discussed. The propulsion system **400** may include a combination of propulsion control modules **410** and propulsion mechanisms **420** that may, either autonomously or in response to remote controls, propel the unmanned vehicle **100** in the air, on the surface of the water, and underwater. The propulsion mechanisms **420** may employ vectored thrust mechanisms that may, for example and without limitation, include turbines and propellers.

Still referring to FIG. **4**, the propulsion system **400** may include a propulsion executive **430**, a propulsion registry **440**, and a transmission control module **450**. The propulsion executive **430** may accept instructions for speed and propulsion type from the navigation executive **470** and may send control signals to direct the desired propulsion mechanisms **420** to engage using the transmission mechanism **460**. The instructions to the propulsion executive **430** from the navigation executive **470** may be in the form of relative changes to speed, including the ability to reverse direction, as well as to the mode of propulsion. Several different types of propulsion systems are contemplated for use in connection with the unmanned vehicle **100** according to embodiments of the present invention. Details regarding the several different types of propulsion systems are provided below.

Referring now to FIG. **5**, an example propulsion mechanism **420** of the unmanned vehicle **100** according to an embodiment of the present invention is discussed in greater detail. Power supplies for all modes of use of the unmanned vehicle **100** may, for example and without limitation, include a variety of motors such as electric **500**, diesel **510**, turbine **520**, and nuclear **530**. Embodiments of the unmanned vehicle **100** according to the present invention may include all or some subset of the hybrid power sources disclosed.

Still referring to FIG. **5**, in some embodiments of the present invention the unmanned vehicle **100** operating in marine and submarine modes may use a plurality of propellers **540** or water jets as vectored thrust. Power may be supplied to propellers **540** by electric motors **500** or by diesel **510**, turbine **520**, or nuclear **530** engines through a computer-controlled transmission **550**. A turbine engine **520** may be substituted for the diesel engine **510**. The diesel **510** and turbine **520** engines may be fueled by, for example and without limitation, common diesel fuel **560**, kerosene, and jet-x. The propulsion control system may include an electronic fuel control **570** to regulate the fuel supplied to the diesel **510** and turbine **520** engines.

Still referring to FIG. **5**, the unmanned vehicle **100** according to embodiments of the present invention may make use of energy captured in storage cells such as batteries **580**. Such storage cells, for example and without limitation, may include high power density lithium polymer batteries or lithium ion batteries. The storage cells may receive energy from the electric motors **500** running as generators when the unmanned vehicle **100** is under power from another source such as diesel **510**, turbine **520**, or nuclear **530** engines. In another embodiment, the storage cells may receive energy from photovoltaic cells **590** that may be mounted to the vehicle body **105** in a variety of mechanical configurations. Such mounting configurations, for example and without limitation, may include axial hinges with actuators to articulate the photovoltaic cells **590** outwardly from the vehicle body **105**. In one embodiment, the photovoltaic cells **590** may be wired to a computer-controlled power control and regulator module. A computer-controlled switch in the power control module may route power from the photovoltaic cells **590** to sets of batteries **580** for recharge depending on the relative charge state of the batteries **580**. The regulator module may monitor and adjust the charge to the batteries **580** used in the first unmanned vehicle **100** embodiment. For example, and without limitation, another embodiment of battery **580** recharge may utilize wave motion to accomplish a low-level recharge by mounting a faraday tube along the fore-to-aft axis of the vehicle body **105**. The faraday tube may be electrically connected to power lines in communication with batteries **580** through a regulator.

Referring now to FIG. **6**, the ballast system of the unmanned vehicle **100** according to an embodiment of the present invention will be discussed. The ballast system, for example and without limitation, may contain mechanisms to control the volume of water and air in one or more ballast chambers **600** to advantageously vary the buoyancy of the unmanned vehicle **100** while submerged and to support selective submerging and re-surfacing of the unmanned vehicle **100**. The ballast system may also be known as the buoyancy system because the system may provide for the selective submerging and re-surfacing of the unmanned vehicle **100** by varying buoyancy. The ballast control mechanism may comprise piping **610** and ports **620** to enable the flow of water into and out of ballast chambers **600**. Electric water pumps **630** may be activated by the ballast control system **640** to control ballast levels which may be monitored by ballast sensors **650**. A pressure tank **660** may be vented into the ballast chamber **600** and the air flow between the pressure tank **660** and the ballast chamber **600** may be regulated by locking electronic valves **670** that may be controlled by the ballast control system **64**. The pressure tank **660** may enable fast evacuation of the ballast chamber **600** and also evacuation of the ballast chamber **600** when other means are not available rapidly.

Ballast ports **680** may be located on the bottom surface of the vehicle body **105** which may enable water to be fed into the ballast tanks **600** when the unmanned vehicle **100** is in motion, which may enable fast submersion. A ballast port **680** located on a device rack **690** positioned on the top of the vehicle body **105** may enable water to be routed into the ballast chambers **600** when the unmanned vehicle **100** is in a top-down position in the water. Filling the ballast chambers **600** while top-down may advantageously enable the unmanned vehicle **100** to autonomously self-right, both at or below the surface of the water. In another embodiment, for example and without limitation, a ballast port **680** located on a device rack **690** may allow routing of air or water to the ballast chambers **600** and, in so doing, may allow the unmanned vehicle **100** to operate underwater without fully surfacing, which may be advantageous for stealth objectives.

Referring now to FIG. **7**, the center of gravity system of the unmanned vehicle **100** according to an embodiment of the present invention will be discussed. The center of gravity system, for example and without limitation, may include mechanisms to control the center of gravity of the unmanned vehicle **100** along the two perpendicular axes for roll and pitch. The center of gravity control system may include internally threaded weights **700** which may encase threaded actuator rods **710** that may be fixed to rotational bearings **720** on one end and electric motor actuators **730** on the other. The electric motor actuators **730** may be controlled by the center of gravity control system **740** that supplies power and signal to the electric motors. Sensors on the linear actuators provide feedback to the center of gravity control system **740** as to position and speed of motion of the controlled, internally threaded weights **700**.

Referring now to FIG. **8**, the pressurization system of the unmanned vehicle **100** according to an embodiment of the present invention will be discussed. The pressurization system, for example and without limitation, may contain a pressure tank **800** that may be able to hold gaseous material, such as air, at a minimum gas pressure of 500 PSI with a sealed hull of an unmanned vehicle **100** to advantageously enable vehicle body **105** strength-to-weight characteristics during selective operation of the unmanned vehicle in the air, on the surface of the water, and below the surface of the water. In one embodiment, the pressure tank **800** may be carried within a compartment inside the vehicle body **105**. In another embodiment, the pressure tank **800** may be affixed to the inside of the sealed hull of the vehicle body **105** which itself defines a watertight chamber. Bidirectional seals in the sealed hull may be applied to any openings, vents, ports, and moving services carried by the vehicle body **105** to maintain a pressurizable space within the unmanned vehicle **100**.

Still referring to FIG. **8** in a further embodiment, for example and without limitation, pressurized spaces within the vehicle body **105** may vent **801** via piping to the exterior of the vehicle body **105**. In one embodiment, for example and without limitation, the piping lines may be vented to the vehicle body **105** exterior through the device rack **690**. In a further embodiment, for example and without limitation, an electrically actuated air pump **802** capable of transferring air into the pressure tank **800** may be connected to an air port via piping line that may employ locking electronic valves **803** to regulate the intake of air through an air port and into the pressure tank **800**.

Still referring to FIG. **8** in a further embodiment, a locking electronic valve **803** that is in the "normally closed" position may be connected to a piping line that may connect to the pressure tank **800** and may vent **801** inside the vehicle body **105**. In a further embodiment, for example and without limitation, a locking electronic valve **803** that is in the "normally closed" position may be connected to a piping line that may vent **801** air from inside the vehicle body **105** to the vehicle body **105** exterior. All internal compartments in the unmanned vehicle **100** may be connected via piping lines to both external vents **801** or to internal vents between compartments.

Continuing to refer to FIG. **8**, pressure sensors **804** may be affixed inside the vehicle body **105** and external to the hull of the vehicle body **105** and may send internal and ambient pressure information to the pressurization control system **805**. The pressure control system **805** may be a set of software programs running on a set of microprocessors that may have control algorithms that may receive inputs from the sensors **804** previously mentioned, may calculate the differential pressure, and may produce outputs to the pressure valve **803** actuator and the air pump **802**. The navigation control system (described in more detail below) may contain logic that may determine the optimal pressure differential set point and may send this information in the form of digital instructions across a computer network to the pressurization control system **805**. The pressure control logic may send control signals to actuator controllers that operate the air pump **802** and relief valve **803**.

To increase the internal pressure in a pressurized compartment inside the vehicle body **105**, the pressure relief valve **803** from the pressure tank **800** may be opened. To decrease the internal pressure in a pressurized compartment inside the vehicle body **105**, the pressure relief valve **803** between the compartment inside the vehicle body **105** and the environment external to the vehicle body **105** may be opened. In both cases, a control algorithm in the pressurization control system **805** may determine the frequency and duration of opening and closing the pressure valves **803**.

A pressure sensor **804** may monitor the pressure tank **800** and may send this signal periodically to the pressure control system **805**. When the pressure in the pressure tank **800** may fall below a given level, as may be configured in the pressure control system **805** logic, the pressure control system **805** may issue a request to pressurize to the navigation system which, in turn, may issue a request to pressurize to the off-board mission control and on-board control system master. These systems may have logic and configurations that may determine when pressurization may be authorized. When pressurization is authorized, instructions are sent to the pressurization system to pressurize.

Referring now to FIGS. **9** and **10**, the control surfaces **900** of the unmanned vehicle **100** according to an embodiment of the present invention will be discussed. In one embodiment of the present invention, control surfaces **900** may be affixed to the vehicle body **105** to advantageously support physical maneuvering of the unmanned vehicle **100** in the air, on the surface of the water, and below the surface of the water. The control surfaces **900**, for example and without limitation, may be comprised of forward canards **905**, rear trim plates **910**, and rudders **230**, all of which may be affixed externally to the vehicle body **105**. In one embodiment, for example and without limitation, a rudder **230** may be mounted on a strut that may be positioned substantially near the stern of the vehicle body **105**. The unmanned vehicle **100** may also include propeller thrusts **920** which may be vectored.

Still referring to FIGS. **9** and **10**, electronic position sensors **1010** may be attached to each control surface **900** and position signals may be relayed to the control surface control system **930**, which may apply control logic to determine desired control surface **900** adjustments. In one embodiment, each of the control surfaces **900** may be independently articulated by electric motor actuators **1000** in response to control signals received by that control surface **900** from the control surface control system **930**. For example and without limitation, the front canards **905** may articulate independently in two directions for a maximum roll condition, and the rear trim tabs **910** may also articulate bi-directionally.

Referring now to FIGS. **11** and **12**, the device rack of the unmanned vehicle **100** according to an embodiment of the present invention will be discussed. The device rack, for example and without limitation, may include a retractable mount **1100** that may articulate from the vehicle body **105** and that may hold sensors **1200**, communication antennae **1210**, and a ballast port **680**. In one embodiment, for example and without limitation, mounting points including mechanical, power and signal mounts may be provided at

the device rack for sensors **1200** and communication antennae **1210**. In another embodiment, ballast ports **680** may be located on either side of the retractable mount **1100**, to which electric wiring and ballast piping may be routed from inside the vehicle body **105** through pressure sealed bulkheads. The device rack may be constructed of various materials including, for example and without limitation, aramid fiber as an outer cover which may be disposed over an aluminum tube frame.

Still referring to FIG. **11**, in one embodiment, for example and without limitation, the device rack may be actuated by electric motors under computer control such that the device rack can be retracted into a "down position" **1110** which may present the least drag and visibility of the unmanned vehicle **100**. In another embodiment, for example and without limitation, the device rack may be actuated by electric motors under computer control such that it can be extruded into a full "up position" **1120** which may present better surveillance, communication, and ballast reach. In one embodiment, for example and without limitation, the retractable mount **1100** may be actuated in the form of a lever arm that may, to accomplish articulation and retraction, swing rotationally about a hinge that may be fixed at a mount point located substantially adjacent to the surface of the vehicle body **105**. In another embodiment, for example and without limitation, the device rack may be actuated in the form of a telescoping member that may extrude and retract in a vector substantially perpendicular to the member's deployment point on the surface of the vehicle body **105**. A person of skill in the art will immediately recognize that the operational value of the multi-mode vehicle **100** may be largely dependent on the payloads the vehicle **100** may carry and how effectively those payloads may be made usable to consumers. Common payloads include various sensors (e.g., cameras, sonar), communications units (e.g., radios) and electronic devices (e.g. electronic warfare). Such payloads come in many shapes, sizes, power requirements and interfaces, as well as environmental ruggedness characteristics. The unmanned vehicle **100** of the present invention may advantageously present a general purpose platform configured to integrate many different payloads. Consumers and/or payload providers may have a need to quickly integrate different sensors into an unmanned vehicle **100**.

In certain embodiments of the present invention, the unmanned vehicle **100** may be configured to carry varying types and amounts of payload in one or more operational modes, including on the surface of water, underwater, and in the air. For example, and without limitation, the vehicle **100** may be configured to carry such payloads internal to the vehicle body (e.g., internally stowed payload **150** in FIG. **1**, as described above). Also for example, and without limitation, the vehicle **100** may be configured to augment the basic hull structure and to receive a mountable payload deck to advantageously provide additional payload capacity, as described in more detail below.

Referring now to FIG. **13**, the payload deck of the unmanned vehicle **100** according to an embodiment of the present invention will be discussed. The payload deck, for example and without limitation, may provide mounting points for an interchanging payload deck **1300**. In one embodiment, the mounting points may include mechanical mounting mechanisms **1310**, power connections **1320**, and signal connections **1330**. Connections and mount points may be fully, hermetically sealed for underwater operation of the unmanned vehicle **100**. The vehicle body **105** may be itself fully sealed and may operate without a payload deck. In one embodiment of the present invention, a payload deck may carry auxiliary solar panels **1340** for electrical recharge and may contain flat form factor batteries **1350** that may provide auxiliary power which may advantageously extend the operational duration of the unmanned vehicle **100**.

Although FIG. **13** demonstrates the unmanned vehicle **100** having the capability to interchange payload decks directly on the vehicle body **105**, the unmanned vehicle **100** may also, for example, and without limitation, include a towing apparatus for towing external payloads. For example, and without limitation, towable payloads may include transport sleds for people, material, and fuel. Such a towing apparatus may support power and signal connections to the unmanned vehicle **100** to which the apparatus is engaged, permitting advantageous employment of auxiliary towable payloads such as, for example, and without limitation, solar sleds to extend running time and sensor arrays to hunt mines and/or submarines. A towable sled, like the unmanned vehicle **100** with which the sled may be deployed, may be configured to operate underwater or on the surface of water, which may be advantageous for missions conducted in dangerous or contested environments where stealth or cover (underwater) is important.

In one embodiment of the external payload towing feature, a Mobile Unmanned Target Practice System may be characterized by mission planning and control instructions advantageously operating some number of unmanned vehicles **100**, each configured with a towing apparatus and a towing sled. Current manned methodologies for positioning, simulating, and assessing military targets limit deployment options and practice locations. The unmanned target practice system described herein may advantageously enable target practice to be done in an expanded range of conditions and locations, allowing for more "organic" target practice. For example, and without limitation, such a target practice system may comprise unmanned vehicles **100** equipped with control systems and mechanical configurations for towing and releasing targets as external payloads. Such towable targets each may be configured with retractable center keels for stability in a surface water environment. The towable targets may also feature retractable target flags. Alternatively, or in addition, towable targets may also be configured as radio-controlled target vessels. For example, and without limitation, an unmanned vehicle **100** may be configured as a "relay station" to remotely operate some number of radio-controlled target vessels.

Referring now to FIG. **14**, the payload deck, for example and without limitation, may provide mechanical, power, and signal connectivity for an additional form of propulsion that may be supplied by a retractable hard sail affixed to an interchangeable payload module. In one embodiment, for example and without limitation, two hard wing sails **1400** with central masts **1410** may be mounted on horizontal cylinders **1420** that may rotate and may be driven by electric motor actuators **1430**. The hard wing sails **1400** may have an aerodynamic wing shape **1440** that may provide additional lift when the unmanned vehicle **100** sailing upwind on the surface of the water. The hard sails **1400** may be rotated around the axis of their mounting mast **1410**, which may be accomplished by splitting the masts **1410**, articulating the sections independently, and mounting electric motor actuators **1480** between mast sections **1410**. The hard sails **1400** can be rotated in two axes and stowed in the payload bay in a horizontal position **1490**. Position sensors may be mounted on the actuators between mast sections **1410** that may be connected to the navigation control system through a wiring connection that may run through bulkhead connectors between the payload deck and the vehicle body **105**.

Still referring to FIG. **14**, for example and without limitation, solar panels **1450** may be affixed to the outer surfaces of the hard sails **1400** which may provide solar recharge capability. The solar panels **1450** may be connected to the payload electrical system which may be connected to the vehicle electrical power system through a bulkhead connector between the payload deck **1460** and the vehicle body **105**. Additional solar panels **1470** may be mounted in the bed of the payload deck for additional solar energy collection and also may be connected to the vehicle electrical power system. In other embodiments, the payload deck, may provide mechanical, power, and signal connectivity for payload modules that may provide auxiliary capabilities in the form of, for example and without limitation, wind energy collectors, video surveillance, and weapons systems.

As described above, the device rack and/or payload deck may provide mechanical, power, and signal connectivity for any number of interchangeable payload modules and/or auxiliary mounts. In this manner, the unmanned vehicle **100** may be outfitted with working appendages of various form and function. Such appendages may advantageously provide utility in multiple modes, as the appendages may be integrated with the body **105** of the unmanned vehicle **100** so that unmanned vehicle **100** may operate effectively in the air, on water, and underwater. Such appendages may be configured with specialized capabilities (e.g., magnetic, telescopic) or specialized tools, depending on the needs of a particular mission.

In one embodiment, for example and without limitation, the payload deck may support a single (e.g., "simple") arm and gripper, which may be positioned in a substantially-central payload bay (e.g., interior compartment) of the unmanned vehicle **100**, which may be advantageous in terms of reach capability. In another embodiment, the payload deck may support a "bat wing" configuration, which may be defined as two appendages each characterized by a shoulder, some number of arms, and some number of grippers. For example, and without limitation, a bat wing appendage configuration may include two appendages attached, respectively, to each side of the unmanned vehicle **100**, and each having a "shoulder" mechanism that may support motion with three degrees of freedom. Each appendage may also include arm sections having connecting "elbows," and each elbow may support motion with either two or three degrees of freedom. Each appendage may also include hand sections, each of which may have gripping/holding capability and may support motion with three degrees of freedom at a "wrist." Also for example, and without limitation, each appendage may comprise a flexible, thin film material positioned between the arm sections that form wings that may be made of (or, alternatively, coated with) thin-film solar. Advantages of "bat wing" design for use with a multi-mode unmanned vehicle **100** is that the design may provide efficient retraction and storage for surface efficiency, increased wing surface for air or sub-surface gliding, solar energy harvesting either in water surface mode or slightly sub-surface, and wind propulsion in water surface mode.

A person of skill in the art will immediately recognize that employing the unmanned vehicle **100** to carry heavy payloads, as in the examples illustrated in FIGS. **13** and **14** and subsequently described above, the vehicle **100** may be expected to experience increased displacement in the water. To counteract the negative impact on performance that increased displacement may cause, the hull design shown and described above for FIGS. **1-3** may be advantageously altered to include an additional sponson.

In one embodiment of the present invention, as illustrated in FIG. **24**, a center sponson **2410** may be added to the hull structure of the vehicle **100** (hereinafter referred to as vehicle embodiment **2400**) and may be centrally positioned between the two existing sponsons **200** to advantageously increase payload carrying capacity for the vehicle **2400** overall. More specifically, the center sponson **2410** may create additional lift through increased displacement and upward force from water flow as the center sponson **2410** moves forward through water. As a direct consequence of this upward force, high performance characteristics may be maintained because, as speed increases, the vehicle **2400** may lift onto the primary port and starboard sponsons **200** which may advantageously remove drag that may be caused by the additional surface area introduced by the center sponson **2410**.

Still referring to FIG. **24**, the front of the sponson **2410** toward the bow of the vehicle **2400** may be characterized by a deep V-Hull shape **2420**. As the sponson **2410** transitions aft, the sponson **2410** may flatten out to a low deadrise hull and pad bottom **2430**. The center sponson **2410** so designed may advantageously provide additional lift when operating on the surface of water because the sponson **2410** may provide displacement that increases as it descends below the water line. The angle and shape of the center sponson **2410** may provide lift as water flows across it from bow to stern of the vehicle **2400**. On either side of the center sponson **2450**, a gap **2450** may be defined between the center sponson **2410** and each side sponson **200** (port and starboard). This gap **2450** may define part of the tunnel **250** (as described above, except necessarily split by the center sponson **2450** into two generally parallel tunnels) that may allow for air flow and lift at higher speeds in such a way as to advantageously maintain good high speed performance of the vehicle **2400**.

Referring to FIGS. **25**, **26**A, and **26**B, additional characteristics of the sponson **2410** of the vehicle **2400** are now described in detail. For example, and without limitation, the center sponson **2410** may define an inclined plane as it moves aft (e.g., progress from first point **2410** through second point **2510** to third point **2430**), which may advantageously provide lift in addition to displacement of the sponson **2410** when vehicle **2400** is moving. Viewed from front to rear of the vehicle **2400**, the sponson pad may be above the port and bow sponson portion relative to water line (**2610** such that at high speeds, the sponson **2410** may remain above the water line. The design of the sponsor **2410** is such that a gap **2620** may be maintained on either side of the center sponson **2410** to advantageously allow air flow and lift which may advantageously maintain stability with low drag. The gap **2610** may be sized relative to total tunnel volume and tunnel width (**2630**).

In another embodiment of the present invention, as illustrated in FIG. **27**, outboard extensions **2710** may be added to the hull structure of the vehicle **100** (hereinafter referred to as vehicle embodiment **2700**) on both port and starboard sponsons **200** to advantageously increase payload carrying capacity. In yet another embodiment, the sponson extensions **2710** may be removable. In yet another embodiment, the extensions **2710** may be part of the base hull mold. The addition of sponson extensions **2710** may increase the displacement of the vehicle **2700** at low speeds as payload weight increases. The addition of the extensions **2710** outboard of the current vehicle **100** profile may advantageously add roll stability at low off-plane speeds while maintaining good high performance characteristics because a) as speed increases, the sponson extensions **2710** may rise up causing

less surface contact and therefore less drag, and b) the center tunnel configuration **250** configured to control air flow and lift may be maintained. The sponson extensions **2710** may exhibit minor air drag effects at very high speeds.

For example, and without limitation, the sponson extensions **2710** may exhibit one or more of the following characteristics:

(1) positioned equilaterally port and starboard;

(2) constructed of the same aramid material as the vehicle hull (e.g., carbon fiber);

(3) shaped to follows the hull contour;

(4) each external sponson **2710** may runs aft and terminate where the vehicle transom begins (i.e., stepped hull shape ends);

(5) the front of each extension sponson **2710** may begin just aft of the vehicle sponson bow rake (i.e., where the sponsons flatten out);

(6) in one embodiment, sponson extensions **2710** may be removable (e.g., affixed to the hull with water proof bolt assemblies);

(7) in another embodiment, external sponsons **2710** may be made as part of the hull mode (e.g., permanent);

(8) the external sponson width may be adjusted depending on the payload weight;

(9) the external sponson width may vary in width asymmetrically to allow for more displacement where the payload is located;

(10) the starboard external sponson **2740** may be characterized by through ports **2730** that may allow water to flow freely between it and the starboard main sponson (e.g., this feature may advantageously facilitate for self-righting of the vehicle **2700**).

Still referring to FIG. **27**, and referring additionally to FIGS. **28**A and **28**B, additional characteristics of the sponson extensions **2710** of the vehicle **2700** are now described in detail. For example, and without limitation, the bottom of the external sponson **2710** starts above the external "water line" step **2880** that is longitudinal along the hull **200**. The aft end of the external sponson **2710** may terminate where the transom begins **2740** and may not overhang the stepped portions of the hull. The width **2890** of the external sponson **2710** may be variable depending on payload weight. A port location **2710** that allows water flow between starboard external and internal sponsons **2710** may be necessary for self-righting. (Not shown: a port side water port may be added to enable underwater multi-mode operation.)

Referring now to FIG. **15**, the navigation control system **1500** of the unmanned vehicle **100** according to an embodiment of the present invention will now be discussed in more detail. The navigation control system **1500**, for example and without limitation, may act as the on-board governor of the speed, direction, orientation, mode and propulsion type for operation of the unmanned vehicle **100**. Navigation of the unmanned vehicle **100** includes both underwater and air glide capabilities as transit route alternatives. Underwater activity may include powered or un-powered operation (e.g., underwater glide). Advantageous underwater activity may include "sit and wait," "power through," or "glide until." Advantageous air activity may include air drop into high seas, which may involve picking an angle of entry and direction of entry that may be best matched to prevalent wave patterns. Examples of advantageous use of the multi-mode navigation capabilities described above may include patrolling coastal areas in the surf zone, navigating through storm conditions, air drop search and rescue in heavy seas, optimizing energy use through all seas states, and surfing (riding) waves to save energy. Other advantageous uses of the capabilities described above may involve underwater current vectoring and may include merging with (riding) underwater currents for motion, avoiding underwater currents that oppose navigation direction, and exploiting underwater thermals.

In one embodiment, for example and without limitation, the navigation control system **1500** may order functional responses from a navigation executive **470**, control surfaces **900** and control surfaces control system **930**, propulsion executive **430**, ballast control **640**, and center of gravity **740** subsystems. The multi-mode navigation control system **1500** may enable the unmanned vehicle **100** to operate on the surface of the water, submerged underwater, and in controlled glide or flight in the air by coordinated computer control of the vehicle control surfaces **900**, ballast **640**, center of gravity **740** and mode of propulsion **430** according to logic and sensor input that may be matched to the operating environment in which the unmanned vehicle **100** may be operating. The computer-controlled subsystems for each control activity may be connected in a computer network which may enable communication between each control subsystem and coordination by a control executive.

For example, and without limitation, navigation directives may originate from a mission control system **1505** when all systems may be operating normally, or from the on-board master control system **1510** in the event of an exception condition, for example, if the mission control system **1505** may be not operating reliably or if a critical subsystem may be operating abnormally. The navigation executive **470** may translate instructions for consumption by each subsystem. The navigation executive **470** includes a navigation subsystems registry **1520** by which it may register and store information about the navigation subsystems that may be available on the unmanned vehicle **100**, including the signal format and semantics by which instructions may be communicated to them.

As mentioned above, the navigation control system **1500** of the present invention may control navigation and orientation of the vehicle **100** in multiple modes. This capability may be exemplified by the ability to maintain direction and stability at speeds of typically between 100 to 200 knots on the surface of the water, orientation and depth control underwater, and controllable glide and flight paths in the air. The ability to control navigation and vehicle **100** orientation in multiple modes may be achieved by autonomous computer control of vehicle control surfaces **930**, ballast control **640**, and vehicle center of gravity control **740**. The control systems of all three of these elements may themselves be under coordinated control by the multi-mode navigation control system **1500**. Further, the multi-mode navigation control system **1500** may control propulsion **400** which also may affect vehicle **100** orientation in combination with the other navigation systems. The systems that control these elements may employ computer-controlled actuators and feedback sensors for closed loop real-time control.

For example, and without limitation, the multi-mode navigation control system **1500** may include optimization instructions regarding speed and orientation. The orientation control function of the navigation control system may calculate the optimal changes in control surfaces **900** and center of gravity **740** and may send instructions to the navigation executive **470** which may issue instructions to the control surface control system **930** and the center of gravity control system **740**. A velocity control function of the navigation control system **1500** may calculate propulsion required and may send the signal to the propulsion control system **430** via

the navigation executive **470**. A flight control function of the navigation control system **1500** may enable powered flight and aerodynamic gliding.

For example, and without limitation, the mission control system **1505** may send instructions to the navigation executive **470** of the multi-mode navigation control system to initiate a mission segment that has an environmental mode of "air glide to water entry." The navigation executive **470** may, in turn, send instructions over a computer network or internal computer bus to activate the flight control function of the navigation control system **1500** and to prompt other subsystems to become slaves to the flight control function of the navigation control system **1500**. The flight control function may monitor sensor input for altitude, orientation (e.g., roll, pitch, yaw) and speed, and may send control instructions to the control surfaces control system **930** and the center of gravity control system **740**. The flight control system may store parameters for optimal orientation and speed characteristics of the vehicle **100** and may also contain logic to operate the control surfaces **900** and center of gravity **740** accordingly. Altitude and infrared sensor input may be fed to the navigation executive **470** that may indicate approach to the water surface. As this approach occurs, the navigation executive **470** may issue new instructions to the flight control function of the navigation control system **1500** as to optimal orientation for entering the water, and the flight control function may issue instructions based on stored logic to the control surfaces **930** and center of gravity control **740** systems to achieve the optimal vehicle **100** orientation. Acceleration, temperature, and pressure sensor data may be fed to the navigation control systems **1500** that indicate water entry.

When water entry occurs, the navigation executive **470** may send instructions to the flight control function of the navigation control system **1500** to shutoff and may initiate logic for underwater operation that may determine characteristics to achieve stable orientation of the vehicle **100** underwater. Instructions may be sent to the control surfaces **930**, center of gravity **740**, and ballast control **640** systems for this purpose. Also, the navigation executive **470** may send an electronic message over the computer network to the mission control system **1505** signifying that the vehicle **100** has entered and is under the water. The mission control system **1505** may store information that indicates the next mission segment and may also contain logic to translate the segment information into environmental mode of operation, speed, orientation, direction and duration. The mission control system **1505** then may send instructions pertaining to navigation characteristics of the next segment back to the navigation executive **470**. For example, and without limitation, the next segment may be water surface operation at 15 knots with a specified directional heading.

Also, for example and without limitation, the navigation executive **470** may execute logic for surfacing the vehicle **100** that includes instructions to the control surfaces **930**, ballast **640**, and center of gravity **740** systems. Depth, pressure, temperature and directional sensor input may be fed to the navigation executive **470** and, as the vehicle **100** surfaces atop the water, the navigation executive **470** may select the propulsion mode and may initiate propulsion according to configuration parameters stored in computer memory. Speed and direction instructions may be issued by the navigation executive **470** to the propulsion control system **400** and control surfaces control system **930**. Each of these systems may accept sensor inputs, the propulsion system **400** may control the propulsion mechanisms to the determined speed, and the control surfaces control system **930** may operate the control surfaces **900** to achieve the instructed orientation.

When an unmanned vehicle **100** is autonomously navigating between two points in a transit route, the navigation control system **1500** may generate directives to other on-board control system components to change speed and direction based on detected wave activity. The navigation control system **1500** may analyze the wave activity and autonomously adjust the transit route to achieve best speed, energy efficiency, and/or vehicle safety (e.g., least likely to overturn). Alternatively, or in addition, the on-board control systems (including the navigation control system **1500**) may accept instructions from a remote-control station that may notify the unmanned vehicle of weather and/or sea state conditions in order to equip the navigation control system **1500** to select the best mode of vectoring. In one embodiment, the navigation control system **1500** may be put in a "maximum endurance" mode, which may comprise executing algorithms to exploit the most efficient use of the propulsion systems **430** that the vehicle **100** has on board. In a preferred embodiment for endurance, such a configuration may include wind sail propulsion **1400**, current propulsion, underwater glide propulsion, and solar recharge **1450**. In such a hybrid-propulsion configuration, the time endurance of the unmanned vehicle **100** may be virtually unlimited from a motive power standpoint.

For example, and without limitation, water current external to the vehicle **100** may be determined by the navigation control system **1500** from maps and algorithms, and sensors for wind speed and direction may be activated by the navigation control system **1500** to perform data collection. The navigation control system **1500** may be configured with algorithms to choose the most effective path segments and overall plan for minimum energy consumption. For example, and without limitation, if the vehicle **100** is proximity to an ocean current moving from west to east, and also to a prevailing wind moving in substantially the same direction, the navigation control system **1500** may choose a path to tack up wind generally in a westerly direction, and then ride the current in an easterly direction without aid of wind to maximize the time of the path on current propulsion. Alternatively, or in addition, mission control system **1505** algorithms may determine that underwater glide mode is the most desirable mode with the current for surveillance reasons. In this case, the unmanned vehicle **100** may sail east to west on the surface, and then glide underwater west to east. In this mode of operation, very little energy may be consumed and, with solar recharge **1450**, the unmanned vehicle **100** may actually experience a net gain in energy over this path. Employing the systems and mechanisms described above, the navigation control system **1500** may advantageously accomplish autonomous navigation of the unmanned vehicle **100** through various sea states for "fastest, cheapest, safest" patterns, that may include both surface and sub-surface patterns, and that also may include air-drop patterns of entry into an operational environment.

Referring now to FIG. **16**, the on-board control system **1600** of the unmanned vehicle **100** according to an embodiment of the present invention will now be discussed. The on-board control system **1600** may comprise an on-board master control subsystem **1510**, for example and without limitation, that may exercise local authority over all command, control and communications related to operation of the unmanned vehicle **100**. In one embodiment, for example and without limitation, on board control system **1600** may interact with additional subsystems that may include a

mission control system **1505**, multi-mode navigation control system **470**, propulsion and power control system **1610**, device rack control system **1620**, payload control system **1630**, communication control system **1640**, sensor control system **1650**, as well as a perception-reaction system **1605**, self-test and operational feedback control system **1660**, life cycle support and maintenance system **1670**, and external system interaction control system **1680**. The on-board master control system **1510** may enable multi-mode operation, autonomous operation, and remote manual control of the unmanned vehicle **100**.

In one embodiment, for example and without limitation, the on-board master control system **1600** of the present invention may be comprised of software programs that may reside on computer storage devices and may be executed on one or more microprocessors also referred to as central processing units (CPU). Inputs to these software control modules may originate as instructions that may be sent from other on-board control systems, as instructions that may be generated from off-board control systems and communicated to on-board systems, and as sensor data input that the control programs may monitor. The output of the software control programs may be digital control signals that may be translated to electronic control signals that may be consumable by motor-controlled actuators that may operate the mechanical components of the unmanned vehicle **100**. Software control module outputs also may be connected to a computer network on the unmanned vehicle **100** and all control modules may be connected to a computer network onboard the unmanned vehicle **100**.

The unmanned vehicle **100** according to embodiments of the present invention may be configured for rapid integration of various sensors by employing a "plug-in" design approach where interfaces exposed to the systems of the vehicle **100** may be standard and where interfaces exposed to the sensor are variable. The sensor interface may be translated to a standard system **100** interface which may allow the sensor to be "plugged in" to the vehicle's **100** system. This general approach to interfaces may be implemented on several levels and may apply to the following:

(1) Mechanical mounting points;

(2) Signal and Power connections;

(3) Logical interfaces;

(4) Data processing schemes; and

(5) Communication schemes.

Certain embodiments of the present invention may provide one or more of the following advantages:

(a) enablement of rapid swapping of many different payloads in the field;

(b) presentation to payload providers of a readily available integration platform (resulting in shortened development cycles on the order of days and weeks rather than weeks and months).

As described in more detail below, mechanical interfaces, which include signal and power connectors as well as mounting points may be embodied as part of an enclosure that is resistant to the multi-mode environment. A number of embodiments of payload enclosures exist that vary in size, shape and mounting locations within the vehicle **100** that accommodate various sensor interfaces and which adhere to the standard vehicle **100** interfaces so that they may be "plugged in". Also, as described below, "payload control" may be integrated with mechanical, signal and power interfaces and may be extended to include communications control and data processing control. Referring to the system block diagram from the original provisional patent, the architecture is the same and supports the "plug-in" model.

As described above, the on-board control system **1600** may further include the payload control system **1630** that, more specifically, may enable control of a wide variation of payloads and may coordinate the payload behavior with the behavior of the vehicle **100**. For example, and without limitation, payload components may include sensor arrays, robotic devices, unmanned aerial vehicles (launch and recovery), and energy sources such as solar arrays. In certain embodiments of the present invention, the payload control system **1630** may manage multiple payloads simultaneously. A person of skill in the art may immediately recognize that the design and operation of the payload control system **1630** may be similar to the design and operation of the device rack control system **1620**, except that the former **1630** may allow for multiple unknown payloads.

Referring now to FIG. **29**, a schematic of an embodiment of the payload control system **1630** will now be discussed in detail. The payload control system **1630** may include a payload control executive **2902**, individual payload component control modules **2903**, and a payload communication module **2904**. The payload control modules **2903** and payload communication module **2904** may be operably connected to individual payloads **2907**. Using the payload registry **2906**, the payload control executive **2902** may register the payload, the payload devices, the corresponding control modules **2903** and information about how to communicate **2904** to each payload module **2903**. The payload control executive **2902** may receive signals from sensors and instructions from system control components as to desired operation of the payload and information requested from the payload. For example, and without limitation, the payload **2907** may include a high-resolution video camera with articulation and zoom capabilities and its own control actuators and signal processing. The mission control system **1505** may issue instructions to the payload control executive **2902** to turn the camera on and point it in a particular orientation and/or with a particular zoom level. The mission control system **1505** may issue instructions as to the routing and processing of the video information collected. The payload control executive **2902** may translate the instructions received from the mission control system **1505** into instructions and signals the video camera control system can use. Additionally, the payload control executive **2902** may route and translate signals from the vehicle sensors to the camera control system. In this case, the camera control system may be provided orientation of the vehicle **100** such that it could actuate the video camera in accordance with the instructions. The video camera data output would be collected and routed in accordance with the mission control system **1505** instructions.

Referring additionally to FIGS. **30**, **31**, and **32**, the following terms are significant to rapid payload integration as advantageously provided by the present invention:

Payload Enclosure: A payload **3110** may be housed in a payload enclosure **3210** with standard connection **3130**, **3180** and mechanical characteristics **3230** as described above. While the signal connection **3140**, **3150** and power connection **3160**, **3170**, as well as internal mounting schema may be standard, the actual size, shape and external mounting characteristics **3240** may vary depending on location within the vehicle **100** and physical requirements of the sensor. In addition to providing uniform interfaces, the payload enclosure of FIG. **32** may provide protection from the multi-mode environment, and primarily protection from water incursion. For example, and without limitation, this protection may be accomplished with standard pressure seals **3260** and enclosures **3220** designed for the vehicle **100**

environment. The payload enclosure of FIG. **32** may accommodate varying physical characteristics, such as clear viewing apertures **3250** for cameras and below deck mounting for heavy electronics. The following interface descriptions relate to the payload enclosure (FIG. **32**) and connections to it.

Signal Interface: A payload **3110** may be housed in an enclosure **3210**, **3220** with standard interfaces for power **3180** and signal **3130**. Examples of standard signal interfaces connections may include USB, Ethernet, Serial (DB9) and a GIO (General **10**) connection interface with standard pin configurations. These standard signal interfaces may be connected to one side of a water resistant, pressure rated bulkhead connector **3140**, **3160** on the inside of the enclosure **3210**, **3220**. On the outside interface, the quick connect style connector **3140**, **3160** may be connected to a wiring harness **3150**, **3170** with known signal mapping to the internal signal inputs that may be, in turn, connected to the vehicles **100** mission control system **1505** and/or known, identified input locations.

Communications Interface: To accommodate payloads **3110** that require an independent communication channel, there may be internal connections in the enclosure for antennae connections. On the outside interface, environment-proof connectors **3140**, **3160** may be connected to a wiring harness **3150**, **3170** that may terminate at locations where antennae may be secured to the hull of the vehicle **100**.

Power Interface: Inside the enclosure (FIG. **32**) may be another set of standard interfaces for power **3180**, **3190**, which may feature heavier gauge wire for power transmission. Multiple sets of plus and minus paired connections **3180** may be available for various voltages and ground connection. These connectors **3180** may be joined via a bulkhead connector **3160** that may be environmentally resistant and rated for the power to be carried. On the outside interface, the quick connect style connector **3160** may be connected to a wiring harness **3170** that may be on a digitally controlled relay that may turn power off and on as needed to the payload **3110**. This digitally controlled relay may be controlled from the payload control system **1630**.

Mechanical Mounting: Inside the payload enclosure **3210**, **3220** may be a number of standard internally threaded standoffs to which the payload **3110** may be secured. For example, and without limitation, these fasteners may take the form of directly bolting the payload **3110** to the inside of the box or fastening the payload **3110** to an intermediary plate or container that may then be fastened to the standard mounting points **3230**.

Logical Control: As an extension to the original plug-in design of the payload control system **1630**, advantages compared to the known art include configurable components for handling communication paths, data processing of payload generated data, power management of payload power and remote control of the payload. Remote control of the payload may be autonomous logic or direct operator control. The mechanism for this may be described as follows:

Each payload type may be registered with the payload control system **1630**. Part of the registration may include a configuration of the particular payload **3110**. This configuration may be read when the payload **3110** is initiated and may include directives as to which components and logic apply to the payload **3110**. When a payload is installed on the vehicle **100**, it may be registered and configured as "installed". When the payload control system **1630** initiates its control sequence, it may initiate the installed payloads according to the configured logic set and may report initiation status.

Once initialized, the payload control system **1630** may run continuously and may execute according to logic and according to remote operator control. The mechanisms for remote operator control may involve a user operating a control station **3020** performing a read of the payload registration and configuration from the vehicle **100** and activating user control interfaces according to pre-programmed instructions that are part of the payload configuration. Additional remote control may be achieved when the payload has a direct communication link enabled that bypasses the vehicle **100** logic and may enables access to payload controls natively in its own metaphor.

Referring now to FIG. **17**, the off-board mission control system **1700** of the unmanned vehicle **100** according to an embodiment of the present invention will now be discussed. The unmanned vehicle **100** of an embodiment of the present invention may, for example and without limitation, operate in full autonomy, partial autonomy or full manual control modes. The on-board mission control system **1600** may accept signals from the off-board mission control system **1700** (also known as the Master Off-board Management System) that may indicate the degree of control and may establish operation control of the unmanned vehicle **100** by enabling or disabling the required mission control logic. The Master Off-Board Management System **1700** may provide registration, navigation, communication, and network integration of the off-board management subsystem modules and may provide a graphical user interface menu and software module navigation system that may provide access to various modules. Sub-systems may be physically separate but may be available over a network of networks, some number of which may be characterized by different protocols and bandwidth characteristics. The Master Off Board Management System **1700** may integrate various other management and control systems.

Referring now to FIGS. **17** and **18**, a multi-vehicle, multi-mode planning and control system may comprise a central off-board planning and control system, a set of off-board control systems that are networked together with the central control system, a set of unmanned vehicles with on-board vessel control systems, and a networked communication system that connects on-board unmanned vehicle control systems with off-board control systems. For example, and without limitation, FIG. **17** is a schematic overview depicting an embodiment of the functional modules of the off-board mission control system **1700**. The major functional modules of the off-board mission control system **1700** may include a Fleet Management Module **1710**, a Mission Management module **1720**, and a Vehicle Management module **1730**. These and other off-board systems may be connected on a common computer network **1810** where all sub-systems may be uniquely identified and any system may communicate with any other system to send and receive data and digital signals. Off-board control systems **1700** may include software programs and digital storage means that may enable autonomous vehicle control operations, and the off-board systems **1700** also may include human interfaces in the form of "graphical user interfaces" (GUIs) displayed on human readable devices such as flat screen monitors, tablet devices and hand-held computer and cell phone devices.

The present invention may advantageously enable coordinated operations across a large number of unmanned vehicles **100** that may be deployed across the globe. The

unmanned vehicles **100** may have a number of embodiments of operational characteristics and may potentially support a large number of payload variations. The Fleet Management System **1710** may include a fleet inventory module for unmanned vehicles **100**, payloads, and related utility systems. The inventory system may store information on each unmanned vehicle **100**, including vehicle specifications, sub-systems, payloads, sensors, operational status, operational history, current location, and availability. Unmanned vehicle information may be provided to the system **1710** by upload from the unmanned vehicle self-test and operational feedback system, which may be initiated automatically by the unmanned vehicle (as described below). Alternatively, software program, graphical user interface, and input means may be provided by the fleet management system **1710** so that human operators may enter information into the system **1710** manually. Application program interfaces (APIs) or interface services may be provided by means of software modules in the fleet management system **1710** that may allow external computer systems to transmit and receive data without human intervention or, alternatively, with a person simply triggering the data transfer through a user interface but not actually entering the data himself. The software programs that may constitute the Fleet Management system **1710** may be modular and separable from each other, even though these programs may inter-communicate. A subset of the programs that may run logic that interacts with the unmanned vehicle self-test and operational feedback system may be executed separately on devices that may collect unmanned fleet and operational data. These data may then be uploaded to a fleet management system **1710** through a connected network **1810**. Such asynchronous upload capability may be advantageous for inventory situations wherein unmanned vehicles **100** may be briefly powered up and interrogated, before losing data communication with a network **1810** that may be shared with the Fleet Management System **1710**.

Continuing to refer to FIG. **17**, the Fleet Management module **1710** may include a Fleet Inventory module **1712**, a Fleet Logistics Management Module **1714**, and a Fleet Maintenance Module **1716**. The Mission Management module **1720** may include a Multiple Mission Management Module **1722**, a Mission Planning module **1724**, a Mission Simulation and Training module **1726**, a Mission Readiness Module **1727**, a Mission Execution Module **1728**, and a Mission Data Processing module **1729**. The Vehicle Management module **1730** may include a Vehicle Pilot Control Module **1732**, a Vehicle Maintenance Module **1734**, and a Vehicle Readiness Module **1736**. As described above, the Fleet Management modules **1710**, the Mission Management modules **1720**, and the Vehicle Management modules **1730** may be characterized as software programs executing on digital computers with human readable output devices and human input devices. These modules may be connected on a common computer network **1810** and all modules and subsystems may be uniquely identified by network address and unique names that may be registered in a namespace registry with information as to how to communicate with each module. All subsystems of the off-board control system **1700** may be accessible to all other subsystems and may transmit and receive data among each other in sets or individually. Security measures may be added to control access between systems or to systems by selected users.

For example, and without limitation, the Fleet Management System **1710** may include a Fleet Logistics system **1714** that may track spare parts, orders, shipments, and vehicle process status. The Fleet Management System **1710** further may include a Fleet Maintenance System **1716** that may store maintenance records for each vehicle, self-test history, maintenance plans, maintenance orders, and maintenance status. The Fleet Maintenance System **1710** may further contain a software program module that may compare maintenance activity and status for each vehicle against the maintenance plan for each vehicle. The software program may contain algorithms to determine when maintenance events are needed or warranted for each vehicle; and may provide notification of these events by means of reports that may be retrieved by people, of proactive email alerts, or of notifications on human readable computer interfaces. The Fleet Management System **1710** may provide a software program with data retrieval and reporting algorithms, a GUI, and input means for people to interact with the system and retrieve information about the fleet of unmanned vehicles.

Still referring to FIG. **17**, for example and without limitation, the off-board mission control system **1700** may include functions to remotely manage individual unmanned vehicles **100**. In one embodiment, real-time tracking **1710** and video feeds may allow remote operators to control specific unmanned vehicles **100** and to monitor the status of each unmanned vehicle **100** while in mission operation **1720**. In another embodiment, human interfaces for remote operators of unmanned vehicles **100** in the form of graphical user interfaces (GUIs), for example and without limitation, may be displayed on human readable devices such as flat screen monitors, tablet devices, and hand held computer and smart phone devices. Off board mission control databases and software programs may register, classify, and execute mission logic that may have inputs and outputs communicated to and from specific sets of unmanned vehicles **100** or individual unmanned vehicles **100**.

As illustrated in FIG. **18**, in one embodiment, the on board **1600** and off board **1700** systems that may collaborate to control one or more unmanned vehicles **100** may be linked through a common communication network protocol **1810**, for example and without limitation, internet protocol (IP). The common network protocol **1810** may be a communication layer that may work in combination with multiple transmission means that may include radio frequency (RF) and satellite microwave between on board **1600** and off board **1700** systems, as well as wired means such as Ethernet on wired networks. In a further embodiment, the off board systems **1700** may have databases and software programs that may operate in concert and on a shared network **1810** that may extend off board remote control of unmanned vehicle **100** sets. In one embodiment, for example and without limitation, a communication network may enable the off board mission system **1700** to advantageously manage and control many unmanned vehicles **100** within communications range of the shared network **1810**. In a further embodiment, on board subsystems **1600** of many unmanned vehicles **100** may exchange data and digital signals and, in series, may relay those data and digital signals to an otherwise out of range off board control system **1700**, thereby advantageously extending the range of remote control and communication capability across a fleet of unmanned vehicles **100** which may result in coverage of larger operational areas with more unmanned vehicles **100** and fewer human operators.

For example, and without limitation, off-board control systems **1700**, which may comprise databases and software programs, may register, classify, and execute mission logic and may exchange inputs and outputs with specific sets of unmanned vehicles or with individual unmanned vehicles **100**. Such data exchange may be supported by a common

network **1810** that may uniquely identify entities on the network to each other. On-board control systems **1600** may equip an unmanned vehicle **100** to behave autonomously and report events experienced by the unmanned vehicle **100**. Off-board control systems **1700** may direct the operations of sets of unmanned vehicles and may have databases and software programs for storing and executing mission logic. The inputs and outputs exchanged across the network **1810** may enable management and control of many vehicles and missions by the off-board control system **1700**, thereby advantageously covering larger maritime areas with more vehicles and fewer human operators. The off-board management and control systems **1700** also may advantageously enable management of maintenance and logistics of fleets of unmanned vehicles throughout multiple missions over the life cycles of many vehicles. The characteristics of the unmanned vehicle described above (e.g., autonomous multimode operation, small size, and the ability to deploy a large number of vehicles over a target area) pose a fleet, mission, and vehicle management challenge. As described above, the capability of the off-board system to integrate and communicate with the respective on-board modules of some number of unmanned vehicles may facilitate advantageous fleet management activities, such as registration, tracking, locating, and records maintenance (as described in more detail below).

Referring now to FIG. **19**, mission execution functionality is now described in more detail. A Mission Initialization module (Block **1910**) may allow for an orderly and sequential initialization for all mission vehicles. Initialization may include, but is not limited to, the downloading of both critical and non-critical mission data. This data may be secure and/or partitioned data. Initialization also may include, but is not limited to, performance of a "roll call" of all vehicles. This step may provide for a check in of primary, secondary, and/or tertiary platoons of unmanned vehicles. Each vehicle **100** may respond to a roll call with its positive, unique and, as required, encrypted identification. Communication protocols may provide for redundant and periodic identification updates. Initialization also may include, but is not limited to, all unmanned vehicles **100** performing a basic power up self-test (POST) and the reporting of these results. At this stage, the unmanned vehicles **100** may enter the Mission Initiation state (Block **1920**), maybe commanded into a dormant state to await further mission instructions, and/or may be outfitted with unique or mission specific payloads.

At Block **1920**, mission Initiation may comprise the orderly and sequential initiation for all mission vehicles **100**. For example, and without limitation, initiation may include establishing basic and enhanced communication by and between all unmanned vehicles, as well as establishing any external communications dictated by mission needs. Initiation also may include, but is not limited to, the powering up of all on-board systems **1600** and the performance of detailed diagnostic self-tests by all unmanned vehicles **100** involved in the mission (e.g., self-tests of advanced sensors, power systems, control systems, energy systems, and payload systems). At this stage, the initial control modes may be set, the mission directives may be activated, and the unmanned vehicles **100** may be launched either in sequence or in parallel, the latter being advantageous for mass/time critical mission deployment.

At Block **1930**, one or more Mission Execution Control and Tracking modules may allow for the control of each unmanned vehicle **100** as an autonomous unit or units, as a semi-autonomous unit or units assisted from a control center, and/or if the situation or mission requires, as a remotely controlled unit. A remote-control unit/user interface may be implemented, for example, and without limitation, as devices such as Droids, Phones, Pads, Netbooks, Laptops, Joysticks, and Xbox controllers. The control mode precedence may be set prior to the start of the mission. The control system master default precedence may be autonomous mode. In addition, control provisions may be made in unmanned unit logic that may allow a unit to be completely "off the grid" to perform missions that require a high level of stealth, secrecy, and/or security. More specifically, these units may act as their own master and may be programmed to initiate communications at predefined intervals that may be modified as required. These units also may have the ability to go dormant for extended periods of time, which may further support the ability for unmanned vehicles **100** to perform virtually undetectable mission execution.

At Bloc, **1940**, the Mission Execution Control and Tracking modules also may allow for the real time tracking of all unmanned vehicles **100**. This capability may include methods such as satellite tracking, GPS tracking, and transponder-based tracking. Communication channels may be redundant and may utilize various levels of military encryption. Tracking may be performed at the fleet level, yet may also support the ability to zoom in on a specific unmanned vehicle **100**. The specific unmanned vehicle tracking data may be overlaid with detailed data such as live video feeds, real time pilot perspective viewing, sensor displays, and other relative data. Analysis of sensor data by on-board control systems may detect "events" of interest. Data characterizing these events may be stored in the unmanned vehicle on-board control system logic and may be reported a message transmitted to the Mission Control System. For example, and without limitation, an event may be defined as a positive identification of a particular target. Periodic vehicle and fleet level self-tests for tracking may occur as background tasks. These self-tests may flag and log exceptions detected, as well as may send a notification to the Mission Control System depending on the class of the exception.

At Block **1950**, the Mission Execution Operations module may define how the unmanned units **100** perform operational tasks. During a mission, as a primary function, the unmanned vehicle **100** may monitor its ISR (or similar) sensors, as well as sensor input received from external sources (e.g., other unmanned vehicles in the fleet, Mission Control inputs) on a real time basis. As part of this monitoring process, exception handling may be performed. Computational logic may then be performed that may include analysis, decision making, and the execution of a series of tasks to fulfill mission parameters. Also, during a mission, as a secondary function, the unmanned vehicle may monitor its payload sensors. As in the case of primary monitoring, exception handling, analysis, decision making, and mission task specifically related to payload may be performed.

At Block **1960**, the Mission Completion module may be designed to close out the unmanned fleet after a mission, may status all vehicles, may perform any required maintenance of the vehicles, and/or may return them to fleet inventory ready for the next mission. Vehicle recovery may be performed in multiple ways. For example, and without limitation, unmanned vehicles may be driven to a pickup point or recovered on location. The unmanned vehicles **100** may be recovered directly by military personnel, military equipment, by other vehicles in the unmanned fleet and similar recovery methods. The unmanned vehicles **100** may be recovered either above or below water, as well as shore

or rivers edge, and similar locations. Before, during, or after recovery operations, the identity of each unmanned vehicle **100** may be checked, demanded self-tests may be performed, and the status may be reported. Any required vehicle maintenance may be performed including checking all internal and external systems. At this point, the unmanned vehicle may be returned to the fleet and the inventory status may be updated.

Tying the mission-level actions more specifically to on board actions in response, upon vehicle initialization (Block **1910**), the Control System Master **1510** may issue a startup command across a computer network to prompt the on-board mission control system **1600** to perform self-test and operational feedback, and to send an on-line status back to the Control System Master **1510**. At Block **1920**, the on-board mission system **1600** then may issue start up commands to all other on-board systems. Each system may start up, perform a self-test, and forward success or failure messages across the network to the Control System Master **1510**. The Control System Master **1510** may be configured **1700** to start up in autonomous or manual control mode and also may be configured with a designator of the current mission (Block **1930**). If in manual control mode, a ready signal may be sent to the Control System Master **1510** and the on-board systems may await manual commands. If in autonomous control mode, the on-board control system **1600** may be activated with the designator of the current mission and the Control System Master **1510** may hand off primary control to the on board control system **1600**. The Control System Master **1510** may be given back primary control if the on-board control system aborts, is diagnosed as malfunctioning, or is over-ridden by manual control. The on-board control system **1600** may be programmed with mission segments that define navigational, sensor, and payload operating characteristics in a time and logic sequence. At Block **1950**, the on-board control system **1600** may issue continually updated instructions to vehicle subsystems as to course and speed (e.g., vector), mode of operation (air, water surface, subsurface), sensor data collection, stealth, payload operation, and interaction with external environments, events and entities. The on-board control system **1600** may receive a continuous stream of data from sensors and may interrogate sensors for more granular data through instructions to the sensor system. The on-board control system **1600** may issue higher level instructions to subsystems that are decomposed by the vehicle control subsystems into more specific instructions. This decomposition of more general instructions to more specific instructions may be a multi-level process that may result in specific signals consumable by vehicle devices and mechanisms. For example, the on-board control system **1600** may issue an instruction to the navigation control system **1500** to navigate in a directional heading, within a speed range having maximum endurance. The navigation control system **1500** may execute logic and may, in turn, issue lower level instructions over the computer network to the subsystems it controls. The on board control system **1600** may also issue instructions to a power control system **1610** for maximum endurance; a perception-reaction system **1605** as to allowable reaction parameters; the device rack control system **1620** as to device rack orientation; the payload system **1630** as to current operational behavior; the communication control system **1640** as to channels and formats of communication; the sensor control system **1650** as to the environmental sensors to activate and the parameters for each as well as the sensor data to collect; and an external system interaction control system **1680** as to current behavioral attributes. All control subsystems may provide continuous status messages to the on-board control system which may multiplex input status messages and may have logic to translate incoming message and sensor data into instructions back to the subsystems.

Referring now to FIG. **20**, an automated Multiple Mission Management **2000** process may provide a set of sub-systems that may enable a complete, end-to-end capability for planning and executing a number of concurrent missions, which may be advantageous within a large maritime target area wherein a number of missions may be required to successfully cover the area. For example, many coastal areas are made up of a combination of a large open area, a number of zones close to shore with different characteristics, populated harbors, and riverine zones that extend well inland. In such a diverse target area, unmanned vehicles may be air dropped or deployed (man portable) to small surgical inland targets.

The concept of a "mission" may be specific to each unmanned vehicle **100**, and/or may be aggregated across sets of unmanned vehicles. The Multiple Mission System may enable the management of multiple missions throughout the entire mission life cycle. When missions are initiated, they may be recorded by the Multiple Mission System and then throughout each mission life cycle may be tracked, updated, and executed. The Multiple Mission System also may manage concurrently executing missions and may provide a security capability to allow access to only authorized users. Employing the systems and methods described above, the present invention may enable the use of many unmanned vehicles **100** to cover large maritime areas with minimal operators at a fraction of the cost compared to conventional approaches to cover the same area.

Continuing to refer to FIG. **20**, a Mission Planning module **2010** may support modeling of trial missions that employ unmanned vehicle capabilities. More specifically, the Mission Planning module **2010** may allow for constructing coverage grids, time-on station duty cycles, communication parameters, perception-reaction attributes, rules of engagement, rules of notification, exception handling rules, and payload operation. The Mission Planning module **2010** also may allow overlaying the vehicle **100** paths on an accurate digital map of the target coverage area and also may include underwater mapping. For example, and without limitation, the modeling capability described above may be used to simulate missions of fleets of unmanned vehicles **100**. Such simulation may be advantageous for purposes of training and/or for planning and strategy.

For example, and without limitation, a Mission Simulation and Training module **2020** may enable mission plans to be "run virtually" with various scenarios including variations in weather, sea state, and external system encounters. Operators may interject simulated manual control of unmanned vehicles. The Mission Simulation and Training module **2020** may provide a valuable estimate as to the likely success of the planned mission under various scenarios.

Also, for example, and without limitation, a Mission Readiness module **2030** may enable planned missions to become ready for execution. When a planned mission is put in "prepare" mode, the mission preparation module may interact with the Fleet Management systems **1710** to determine logistics activities and may enable the user of the system to assemble a mission fleet of unmanned vehicles **100**. Mission Preparation functionality may provide tracking and reporting functions to allow the user to know the state of mission readiness.

Also, for example, and without limitation, a Mission Execution System **2040** may provide the functions necessary

to begin and complete a successful mission of a fleet of unmanned vehicles **100**. FIG. **19** illustrates a high-level flow diagram of exemplary functions provided by the Mission Execution System modules.

Also, for example, and without limitation, a Mission Data Processing System **2050** may receive and record mission data transmitted from the unmanned vehicles **100**. A majority of missions may be presumed to relate to data gathering for intelligence, surveillance and reconnaissance (ISR) purposes. The Mission Data Processing system **2050** may collect and process large amounts of data and may extract the most useful information out of the data in near real time. The Mission Data Processing system **2050** may perform complex data pattern processing in addition to raw storage and reporting.

FIG. **21** illustrates an embodiment of integrating various off-board management and control processes with on board control processes of a set of unmanned vehicles **100**. For example, and without limitation, a mission may be planned and simulations of a mission may be run in a data center in the United States, subsequently the mission may be made available to a mission control center in East Africa. The mission control center may check for fleet availability to populate the mission and may transmit a request through secure communication channels for unmanned vehicles. A vehicle repository that may be, for example, and without limitation, controlled by military personnel or military subcontractors in Europe, may process the request. Unmanned vehicles in Europe may be run through maintenance diagnostics to validate readiness, then may be loaded on transport aircraft equipped with unmanned remote launch apparatus. The loaded unmanned vehicles may be flown to a target area off the coast of East Africa and may be air dropped over a pre-planned pattern in accordance with the mission planned in the United States. Mission execution responsibility may be transferred to a mission control center in the Middle East, again through secure communication channels. After the mission is concluded, fleet management may be transferred back to a control center in Europe and the unmanned vehicles may be retrieved by or driven to designated destinations (either mobile or static). Upon successful retrieval, the unmanned vehicles involved in the complete mission may be returned to the vehicle repository.

Swarming may be defined as a deliberately structured, coordinated, and strategic way to strike from all directions, by means of a sustainable pulsing of force and/or fire, close-in as well as from stand-off positions. Swarming involves the use of a decentralized force in a manner that emphasizes mobility, communication, unit autonomy, and coordination/synchronization. In the context of unmanned vehicles, "swarming" relates to coordinating a collection of vehicles such the vehicles' movements are orchestrated in relation to each other.

In one embodiment of mission planning and control, multi-mode swarm control advantageously solves the problem of having a number of unmanned vehicles each moving in its own pre-determined path in a coordinated spatial and time pattern where the unmanned vehicles are in close proximity. Unmanned vehicle swarms may locate a collection of unmanned vehicles in a target zone at desired times and locations. The unmanned vehicles may proceed at a collection of coordinated paths and speeds. Paths may be defined by geo-coordinates (e.g., latitude and longitude) and depth (e.g., altitude), so that paths may be said to be "three dimensional". Additionally, a swarm may include a number of unmanned vehicles deployed by air drop following a pre-determined glide path. Unmanned vehicle multi-mode swarm technology may include coordinated on-board and off-board control. By contrast, conventional swarm control involves swarming in one "mode", meaning vessels operate in one of three modes (e.g., air, surface, sub-surface) rather than in two or three modes. As described herein, multi-mode control guides unmanned vehicles in three modes. A single unmanned vehicle may traverse multiple modes executing a transit route.

As described above, a military mission may have a specific objective in a specific area and may be time-bound. Multi-mode swarm, as described herein, may be accomplished at the mission level. As illustrated in FIG. **22**, three-dimensional (3D) deployment may be considered a special category of multi-mode swarm control driven by the mission planning. 3D Deployment missions may be accomplished on a global scale, although the mission "target zone" may be in a concentrated and designated area. Swarms, in such a scenario, may be comprised of one or more groupings, and such groupings may be hierarchically organized (e.g., analogous to military units: team, platoon, squadron). A mission plan, in this same scenario, may be thought of as a set of mission maps.

For example, and without limitation, a 3D Deployment may comprise an airdrop of a squad (10) of unmanned vehicles, deployment of a platoon (40) of unmanned vehicles off of a ship, and deployment of a team (4) of unmanned vehicles out of a submarine. For example, and without limitation, each of the unmanned vehicles may be equipped with a collision avoidance system (CAS) which may provide awareness of proximate vehicles and/or objects.

In one embodiment of a basic swarm method, each unmanned vehicle may be loaded with a mission track (e.g., one or more transit paths) with location, speed, time, and path tolerance. Missions may be coordinated such that involved unmanned vehicles' paths do not collide. In the example embodiment, each group may proceed from the "drop zone" on a transit path specified by the off-board control system. At a specified time, each group may proceed to its own specified location, at which point the swarm may be considered to have achieved platoon size. Each grouping may be deployed to a location that may be a specified distance from a target. Upon a specified schedule, all mission assets (e.g., unmanned vehicles) may move toward the mission target zone, each executing planned movements in support of the mission and, as appropriate, executing autonomous movements in response to unplanned stimuli but no so as to jeopardize the mission. For example and without limitation, planned movements may call for the air dropped squad to split off into two teams, for the platoon to split into four squads, and for the team to stay intact. In such a manner, all vessels and groups in the swarm may be coordinated over time, 3D location, and transit path.

A skilled artisan will note that one or more of the aspects of the present invention may be performed on a computing device. The skilled artisan will also note that a computing device may be understood to be any device having a processor, memory unit, input, and output. This may include, but is not intended to be limited to, cellular phones, smart phones, tablet computers, laptop computers, desktop computers, personal digital assistants, etc. FIG. **23** illustrates a model computing device in the form of a computer **810**, which is capable of performing one or more computer-implemented steps in practicing the method aspects of the present invention. Components of the computer **810** may include, but are not limited to, a processing unit **820**, a system memory **830**, and a system bus **821** that couples

various system components including the system memory to the processing unit **820**. The system bus **821** may be any of several types of bus structures including a memory bus or memory controller, a peripheral bus, and a local bus using any of a variety of bus architectures. By way of example, and not limitation, such architectures include Industry Standard Architecture (ISA) bus, Micro Channel Architecture (MCA) bus, Enhanced ISA (EISA) bus, Video Electronics Standards Association (VESA) local bus, and Peripheral Component Interconnect (PCI).

The computer **810** may also include a cryptographic unit **825**. Briefly, the cryptographic unit **825** has a calculation function that may be used to verify digital signatures, calculate hashes, digitally sign hash values, and encrypt or decrypt data. The cryptographic unit **825** may also have a protected memory for storing keys and other secret data. In other embodiments, the functions of the cryptographic unit may be instantiated in software and run via the operating system.

A computer **810** typically includes a variety of computer readable media. Computer readable media can be any available media that can be accessed by a computer **810** and includes both volatile and nonvolatile media, removable and non-removable media. By way of example, and not limitation, computer readable media may include computer storage media and communication media. Computer storage media includes volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information such as computer readable instructions, data structures, program modules or other data. Computer storage media includes, but is not limited to, RAM, ROM, EEPROM, FLASH memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by a computer **810**. Communication media typically embodies computer readable instructions, data structures, program modules or other data in a modulated data signal such as a carrier wave or other transport mechanism and includes any information delivery media. The term "modulated data signal" means a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal. By way of example, and not limitation, communication media includes wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, radio frequency, infrared and other wireless media. Combinations of any of the above should also be included within the scope of computer readable media.

The system memory **830** includes computer storage media in the form of volatile and/or nonvolatile memory such as read only memory (ROM) **831** and random-access memory (RAM) **832**. A basic input/output system **833** (BIOS), containing the basic routines that help to transfer information between elements within computer **810**, such as during start-up, is typically stored in ROM **831**. RAM **832** typically contains data and/or program modules that are immediately accessible to and/or presently being operated on by processing unit **820**. By way of example, and not limitation, FIG. **23** illustrates an operating system (OS) **834**, application programs **835**, other program modules **836**, and program data **837**.

The computer **810** may also include other removable/non-removable, volatile/nonvolatile computer storage media. By way of example only, FIG. **23** illustrates a hard disk drive **841** that reads from or writes to non-removable, nonvolatile magnetic media, a magnetic disk drive **851** that reads from or writes to a removable, nonvolatile magnetic disk **852**, and an optical disk drive **855** that reads from or writes to a removable, nonvolatile optical disk **856** such as a CD ROM or other optical media. Other removable/non-removable, volatile/nonvolatile computer storage media that can be used in the exemplary operating environment include, but are not limited to, magnetic tape cassettes, flash memory cards, digital versatile disks, digital video tape, solid state RAM, solid state ROM, and the like. The hard disk drive **841** is typically connected to the system bus **821** through a non-removable memory interface such as interface **840**, and magnetic disk drive **851** and optical disk drive **855** are typically connected to the system bus **821** by a removable memory interface, such as interface **850**.

The drives, and their associated computer storage media discussed above and illustrated in FIG. **23**, provide storage of computer readable instructions, data structures, program modules and other data for the computer **810**. In FIG. **23**, for example, hard disk drive **841** is illustrated as storing an OS **844**, application programs **845**, other program modules **846**, and program data **847**. Note that these components can either be the same as or different from OS **833**, application programs **833**, other program modules **836**, and program data **837**. The OS **844**, application programs **845**, other program modules **846**, and program data **847** are given different numbers here to illustrate that, at a minimum, they may be different copies. A user may enter commands and information into the computer **810** through input devices such as a keyboard **862** and cursor control device **861**, commonly referred to as a mouse, trackball or touch pad. Other input devices (not shown) may include a microphone, joystick, game pad, satellite dish, scanner, or the like. These and other input devices are often connected to the processing unit **820** through a user input interface **860** that is coupled to the system bus, but may be connected by other interface and bus structures, such as a parallel port, game port or a universal serial bus (USB). A monitor **891** or other type of display device is also connected to the system bus **821** via an interface, such as a graphics controller **890**. In addition to the monitor, computers may also include other peripheral output devices such as speakers **897** and printer **896**, which may be connected through an output peripheral interface **895**.

The computer **810** may operate in a networked environment using logical connections to one or more remote computers, such as a remote computer **880**. The remote computer **880** may be a personal computer, a server, a router, a network PC, a peer device or other common network node, and typically includes many or all of the elements described above relative to the computer **810**, although only a memory storage device **881** has been illustrated in FIG. **23**. The logical connections depicted in FIG. **23** include a local area network (LAN) **871** and a wide area network (WAN) **873**, but may also include other networks **140**. Such networking environments are commonplace in offices, enterprise-wide computer networks, intranets and the Internet.

When used in a LAN networking environment, the computer **810** is connected to the LAN **871** through a network interface or adapter **870**. When used in a WAN networking environment, the computer **810** typically includes a modem **872** or other means for establishing communications over the WAN **873**, such as the Internet. The modem **872**, which may be internal or external, may be connected to the system bus **821** via the user input interface **860**, or other appropriate mechanism. In a networked environment, program modules depicted relative to the computer **810**, or portions thereof,

may be stored in the remote memory storage device. By way of example, and not limitation, FIG. **23** illustrates remote application programs **885** as residing on memory device **881**.

The communications connections **870** and **872** allow the device to communicate with other devices. The communications connections **870** and **872** are an example of communication media. The communication media typically embodies computer readable instructions, data structures, program modules or other data in a modulated data signal such as a carrier wave or other transport mechanism and includes any information delivery media. A "modulated data signal" may be a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal. By way of example, and not limitation, communication media includes wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, RF, infrared and other wireless media. Computer readable media may include both storage media and communication media. Some of the illustrative aspects of the present invention may be advantageous in solving the problems herein described and other problems not discussed which are discoverable by a skilled artisan. While the above description contains much specificity, these should not be construed as limitations on the scope of any embodiment, but as exemplifications of the presented embodiments thereof. Many other ramifications and variations are possible within the teachings of the various embodiments. While the invention has been described with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best or only mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the description of the invention. Also, in the drawings and the description, there have been disclosed exemplary embodiments of the invention and, although specific terms may have been employed, they are unless otherwise stated used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention therefore not being so limited. Moreover, the use of the terms first, second, etc. do not denote any order or importance, but rather the terms first, second, etc. are used to distinguish one element from another. Furthermore, the use of the terms a, an, etc. do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced item.

With additional reference to FIGS. **33-41**, another embodiment of an unmanned vessel will be described. The unmanned vehicle according to this embodiment is configured for semi-submersible launch and recovery of payload objects. Of course, such embodiment may include any of the features described above with respect to other embodiments. As will be described in further detail below, the present embodiments include a well-deck built into a hull (e.g., a catamaran-like hull) and include the ability to flood the stern of the host vessel, the ability to control buoyancy through a buoyancy control system, and/or the ability to control water depth in the well deck and pitch of the well deck by controlling the center of buoyancy. The ability to position the host vessel in an advantageous position and orientation, may also be provided so the payload can most effectively be launched and recovered. Positioning is relative to the payload and environment which may be particularly important in higher sea states.

It should be noted that the present embodiment preferably provides the ability of the host vessel to navigate autonomously with high performance characteristics when not flooded, the ability of the host vessel to maintain headway and navigate while the well deck is flooded, and/or the ability of the host vessel to sense location and position of launched and recovered payload objects as they move away or toward the well deck.

For this description the payload objects are unmanned vessels, such as unmanned surface vessels ("USV"), unmanned underwater vessels ("UUV") or remote operated vehicles ("ROV") that can be free-launched or launched using a winched tethered tow, for example.

Initially, referring to FIG. **33**, a diagram is shown that illustrates the six degrees of freedom related to the operation of an unmanned vehicle according to embodiments of the present invention. A position of the well deck is preferably controlled within six degrees of freedom including roll, pitch, yaw, up/down, forward/reverse and right/left.

FIG. **34** is a schematic diagram illustrating the layout of a buoyancy control system **3402** for an unmanned vehicle **3400** according to an embodiment of the present invention. In this embodiment, the example of an unmanned vehicle **3400** includes many features described above but is not limited thereto. Other combinations of features described herein are contemplated as would be appreciated by those skilled in the art. Here, the vehicle body may include a pair of substantially parallel sponsons **3404**, **3406** coupled together on opposite sides of a recessed well deck **3408** in a stern portion of the vehicle body. The recessed well deck **3408** is configured to stow a payload as will be described below.

Although not shown here, a propulsion system is configured to propel the unmanned vehicle **3400**, a maneuvering system is configured to maneuver the unmanned vehicle, and a vehicle control system is configured to control a speed, an orientation, and a direction of travel of the unmanned vehicle in combination with the propulsion system and the maneuvering system. Various embodiments of such systems are described above with reference to FIGS. **4-15** and are not described again here. A sensor system includes a plurality of environmental sensors configured to sense environmental and operational characteristics for the unmanned vehicle, and at least one power supply is configured to provide power to the propulsion system, the maneuvering system, the vehicle control system, the buoyancy control system, and the sensor system, as also described above with respect to other embodiments.

As described above with reference to FIG. **6**, the ballast system may contain mechanisms to control the volume of water and air in one or more ballast chambers to advantageously vary the buoyancy of the unmanned vehicle while submerged and to support selective submerging and re-surfacing of the unmanned vehicle. The ballast system may also be known as the buoyancy system because the system may provide for the selective submerging and re-surfacing of the unmanned vehicle by varying buoyancy. The ballast control mechanism may include piping and ports to enable the flow of water into and out of ballast chambers. Electric water pumps may be activated by the ballast control system to control ballast levels which may be monitored by ballast sensors.

For the buoyancy control system **3402**, ballast containers **3410** are positioned within portions of the vehicle body. A

pump **3412** and valves **3414**, **3416** define a pump and valve system that is configured to vary amounts of water and air in the recessed well deck **3408**. Various other pumps and valves, described above with reference to FIG. **6**, may be included to vary the amount of water and/or air in the ballast containers **3410**. The ballast containers **3410** preferably include at least a ballast container located forward and aft in each of the sponsons **3404**, **3406** to define four quadrants of buoyancy for the unmanned vehicle **3400**. More than four ballast containers **3410** is also contemplated. The buoyancy control system **3402** may include a buoyancy controller **3420** that is configured to individually control the relative buoyancy in each of the four quadrants and the total buoyancy of the unmanned vehicle **3400**. Various sensors, including imaging sensors **3430**, may also be provided and will be described in more detail below.

Water is filled in the recessed well deck **3408** via a combination of the water pump **3412** and actuated valves **3414**, **3416** that allow water into and out of the hull. An air valve **3418** may be used to control air flow in and out of the recessed well deck **3408** of the hull. The pump **3412** may also pump water out. The recessed well deck **3408** can accept water in the hull without damaging internal components as it is designed to be flooded through the use of various seals and channels, not shown, as would be appreciated by those skilled in the art. The combination of total water in the well deck **3408** and the four-quadrant buoyancy control enables control of at least three of the six degrees of freedom: pitch, roll and up/down.

The vehicle control system or navigation control system **1500**, as the on-board governor of the speed, direction, and orientation, will control the other three of the six degrees of freedom: yaw, forward/reverse and right/left.

Referring additionally to FIGS. **36** and **37**, the recessed well deck **3408** includes a payload securing system that may include supports **3602** or cradles or similar structures into which the payload objects **3606**, **3608** (e.g., USV/UUV/ROVs) sit for stability during transit. FIG. **36** is a top view illustrating a semi-submersible launch and recovery unmanned vehicle according to an embodiment of the present invention. FIG. **37** is a perspective rear view illustrating the semi-submersible launch and recovery unmanned vehicle of FIG. **36** on the surface of the water.

The supports **3602** and may have an automated apparatus **3604** to secure the payload objects. For example, for winched tethered tow, the automated apparatus **3604** may include tether lines **3605** that connect to an autonomously controlled reel at a fixed end, and attach to the payload objects **3606**, **3608** at a free end. The tether lines may be multi-purpose to both convey data and power between the USV/UUV/ROVs and the UMMV, as well as mechanically tow the USV/UUV/ROVs.

The vehicle control system **1500**, the buoyancy control system **3402** and the sensor system **1650** define a well deck positioning control system **3500** (FIG. **35**) configured to launch and recover objects **3606**, **3608** of the payload to/from the water while the well deck **3408** is at least partially submerged in water. FIG. **35** is a schematic block diagram illustrating components defining the well deck position control system **3500** for an unmanned vehicle **3400** according to an embodiment of the present invention. The well deck positioning system **3500** may include a well deck positioning controller **3502** configured to provide output signals to actuators **3510-3513** of the buoyancy control system **3402** and to the vehicle control system **1500** in response to input signals from sensors **3520-3524** of the sensor system. Thus, the well deck positioning control system **3500** is a feedback control system taking instructions from the command and control block **3504** as set points, using sensor inputs to determine feedback signals and provide output signals to actuators.

The command and control block **3504**, which may be under operator direction, or receive autonomous instructions as described above, sends positioning instructions to the well deck positioning controller **3502**. Such instructions may include well deck pitch, well deck depth, well deck heading, well deck turn rate or well deck pitch rate, for example. The well deck positioning controller **3502** sends position information back to the command and control block **3504**. The sensors may include orientation **3520**, movement **3521**, water level **3522**, environment **3523** and payload position **3524**. These sensors **3520-3524** provide feedback to the well deck position controller **3502**. The actuators **3510-3513** control flooding of the well deck **3408** and ballast containers **3410** via the four buoyancy mechanisms, water inlet valves, water pumps, air valves and vehicle movement.

An embodiment at least includes the plurality of environmental sensors **3430** including, for example, water level sensors **3522** configured to sense water levels in the ballast containers **3410** and the recessed well deck **3408**, and payload position sensors **3524** configured to sense the position of the payload relative to the payload securing system **3602**/**3604** and the recessed well deck **3408**.

The launch process begins when the UMMV **3400** initiates a launch sequence request from a remote operator or from internal logic executing autonomous mission logic running on resident control systems as described above. The entire sequence of launch and recovery may be under control of the on-board control systems on the UMMV **3400**. The UMMV **3400** floods the recessed well deck **3402**, e.g., in the stern section of the vessel to the mid-ship, by opening flood valves and activating flooding pumps if faster flooding is desired. FIG. **38** is a perspective rear view illustrating the semi-submersible launch and recovery unmanned vehicle **3400** of FIG. **36** partially submerged below the surface of the water.

Water level monitoring sensors **3522** in the well deck **3408** provide feedback to the controller **3502** which also monitors pitch and roll **3520**. Additionally, the buoyancy control system **3402** controls the amount and location of flotation. The buoyancy control system **3402** controls the depth of water in the well deck **3408** and the pitch of the well deck by controlling the amount of flooding and center of buoyancy while monitoring water level and pitch sensors.

When the water in the well deck **3408** is at the desired depth and the pitch of the well deck is at the desired angle, the actual launch of the payload objects **3606**, **3608** (e.g. either USV, UUV or ROV) is initiated. In this phase, the support **3602** or cradle releases the payload object(s) **3606**, **3608** or the object simply floats away from its cradle. The object **3606**, **3609** may or may not be tethered **3605** and may drive away from the UMMV **3400** to perform its mission. FIG. **39** is a perspective rear view illustrating the semi-submersible launch and recovery unmanned vehicle **3400** of FIG. **36** during launch and recovery of the payload object **3606**, **3608**. FIG. **40** is a more detailed rear view illustrating the semi-submersible launch and recovery unmanned vehicle **3400** of FIG. **36** during launch and recovery of the payload objects **3606**, **3608**.

It should be appreciated that the UMMV **3400** may drive away from the payload object(s) **3606**, **3608**, or the objects may drive away from the UMMV. Once the UMMV **3400** achieves separation from the object(s) **3606**, **3608**, the UMMV may stay partially submerged and navigate in that

orientation, may evacuate the flooded water and continue to drive as a surface vessel, or remain floating stationary in its partially submerged orientation, for example.

Orientation sensors **3520** may include positional sensors to provide pitch-roll-yaw and depth position of the UMMV **3400**. Also, sensors **3524** detect location and orientation of payload objects **3606**, **3608** to provide feedback to the command and control block **3504** and/or positioning and payload securing systems. The payload position sensors **3524** may include imaging sensors, e.g., electro-optical or infrared (EO/IR), that are oriented toward payload objects **3606**, **3608** and a remote streaming system (i.e., control and communications of imaging) may be part of the command and control block **3504** or the vehicle control system **1500** to provide feedback to remote human operators. Thus, the well deck positioning control system **3500**, in connection with the vehicle control system, has the capability to dynamically position the UMMV **3400** relative to payload objects **3606**, **3608** and may include communication (wired or wireless) between such objects and the UMMV.

In recovery mode, the UMMV **3400** will return to its semi-submersible condition. The payload object(s) **3606**, **3608** will either drive back over the well deck **3408** for capture or may be captured aft of the UMMV **3400** and then towed back into the well deck. Once the object(s) **3606**, **3608** is/are in position and secured or captured in the well deck **3408**, the UMMV **3400** evacuates the flooded water by pumping it out and returns to its surface operation. Sensors **3522**, **3520** monitor the water level and pitch during the transition from semi-submersible to surface condition. FIG. **41** is a perspective rear view illustrating the semi-submersible launch and recovery unmanned vehicle **3400** of FIG. **36** on the surface of the water after recovery of a payload object **3608** and back on the surface of the water. As illustrated, as part of the payload securing system, a tailgate **3630** is configured to pivot between a down (or launch/recovery) position and an up (or closed/transport) position.

Once the flooded water is pumped out of the well deck **3408** and/or the ballast containers **3410**, the UMMV **3400** may navigate normally and perform high speed maneuvers as desired.

With additional reference to FIGS. **42-51**, another embodiment of an unmanned vessel will be described. The unmanned vehicle according to this embodiment is configured for autonomous hiding. Of course, such embodiment may include any of the features described above with respect to other embodiments. As will be described in further detail below, the present embodiments include an autonomous hiding control system and an autonomous stealth mode executive control. The hiding control system works with the navigation mode executive control to physically position the unmanned vehicle so that it cannot be detected by an item of interest. The stealth mode executive control may provide control to a stealth control system, a thermal cloaking system, an acoustic cloaking system, a radio frequency cloaking system, or a radio frequency imitation system, which operate to prevent detection of the unmanned vehicle by an item of interest.

It should be noted that the present embodiment preferably provides the ability of the host vessel to navigate autonomously while preventing or limiting the risk of detection or harm to the vessel.

Initially, FIGS. **42-47** primarily depict processing characteristics of elements of the invention while FIGS. **48-51** primarily depict physical characteristics of elements of the invention.

Now referring to FIG. **42**, a block diagram of an autonomous hiding system is shown. The autonomy hiding system is comprised of layers of related functionality. Layers providing autonomy **4201** are depicted on the left of FIG. **42**, with layers providing hiding **4202** depicted on the right. There is some overlap between autonomy and hiding in the control layer **4205**. The layers below the top level autonomy and hiding designations of FIG. **42** are organized from left to right as the input queue layer **4203**, integration layer **4204**, control layer **4205**, and vessel operation layer **4206**, which provides the output.

The input queue layer **4203** includes mission planning **4207**, a mission plan **4208**, mission decision algorithms **4209**, sensors **4210**, sensor signal processing **4211**, sensor data fusion **4212**, and sensor data analysis **4213**. The input queue layer **4203** may contain inputs to the system that originate from sensors taking in external environment data, or mission information and decision logic that is pre-programmed by mission planners. The input queue layer contains elements of artificial intelligence in the form of a) mission decision algorithms and b) sensor data analysis including recognition, identification and classification.

The integration layer **4204** may include mission plan integration **4214**, algorithm processing integration **4215**, sensor integration **4216**, and sensor data and analysis integration **4217**. The integration layer **4204** conveys data generated in the Input Queue Layer **4203** to the Control Layer **4205**. To accomplish this, the Input Queue Layer **4203** components must be integrated into this system with data, electrical, power, and mechanical connections. If physical integration is required, the integration may include waterproofing all components, signals and power.

The control layer **4205** may include a vessel control system **4218**, hiding control system **4219**, navigation control system **4220**, and stealth control system **4221**. The control layer **4205** may contain components that process the input data and translate to signals that control "hiding" system components and therefore hiding behavior.

The vessel operation layer **4206** may include the vessel systems that cause the vessel to perform certain behaviors. The vessel operation layer **4206** may include stealth hiding signature suppression systems **4223** and physical hiding navigation modes **4222**. The stealth hiding signature suppression systems **4223** may include a thermal cloaking system **4227**, an acoustic cloaking system **4228**, a radio frequency cloaking system **4229**, and a radio frequency imitation system **4229**. They physical hiding navigation modes **4222** may include a navigation system **4224**, which may include a propulsion system, a steering system, and control surfaces, a buoyancy system **4225**, and a ballast system **4226**. The buoyancy system **4225** and the ballast system **4226** may be components of the maneuvering system.

Turning to FIG. **43**, this flowchart depicts logic used by the mission execution control **4401** in determining what hiding behaviors to execute. The process begins with a sensor **4301**, **4302** and mission plan **4303** input. The sensor **4301**, **4302** input may be received from a transient object detection sensor **4301** or an environmental awareness sensor **4302**. A transient object detection sensor **4301** may include, but is not limited to, an electro-optical sensor **4308**, an infrared sensor **4309**, a radar sensor **4310**, a LIDAR sensor **4311**, an acoustic sensor **4312**, and a sonar sensor **4313**. An environmental awareness sensor **4302** may include, but is not limited to, a GPS sensor **4314**, a compass **4315**, a gyro sensor **4316**, and an inertial navigation system (INS) **4317**.

The inputs are processed and sent to decision algorithms that generate messages, which are provided to the hiding control system **4307**.

Sensors **4301** may be attached to the unmanned vehicle for the purpose of detecting items of interest, which may be transient objects. The sensors **4301** may be referred to as transient object detection sensors. The sensors **4301** may provide data to a signal processing block **4304**, which may detect an item of interest and provide an item of interest signal to an artificial intelligence block **4305**, which may identify or classify the item of interest. The artificial intelligence block **4305** may be part of the vehicle control system. The artificial intelligence block **4305** may provide a classification signal. The classification signal may be provided to the mission execution control **4306** and may be utilized by the propulsion system, maneuvering system, vehicle control system, or buoyancy control system. The classification signal may be determined by the artificial intelligence block **4305** based on the item of interest classification. Items of interest may include, but are not limited to aquatic vessels, humans, mines, aerial vehicles, and chemicals. Items of interest may be classified as one of the listed types of items of interest after identification.

The unmanned vehicle may have any combination of sensors **4308**, **4309**, **4310**, **4311**, **4312**, and **4313**. Examples of sensor **4301** configurations include, but are not limited to, a single optical camera, some combination of sensors **4308**, **4309**, **4310**, **4311**, **4312**, and **4313**, and all of sensors **4308**, **4309**, **4310**, **4311**, **4312**, and **4313**. The enumeration of sensors **4301** may be representative of many embodiments but is not exhaustive.

Sensors **4302** may be attached to the unmanned vehicle to provide environmental information. Examples of environmental information include, but are not limited to, location on earth, vessel heading and course, and vessel orientation in water or air. Environmental information input is consumed by mission planning **4303** and execution **4306** modules. Additional sensors **4302** may be included but are not specifically enumerated in FIG. **43**. Examples of additional sensors **4302**, include, but are not limited to, sensors detecting the presence of chemicals or nuclear waste and sensors adapted to provide an indication of water quality. The presence or absence of particular environmental features may be defined as an item of interest. Output from the sensors **4302** may be provided to signal processing block **4304** to detect an item of interest. It is anticipated that new environmental sensors **4302** will become available and are considered within the scope of this disclosure.

Items of interest may include transient objects detected by sensors **4301**, which may include ships, boats, swimmers, submarines, mines, aerial objects, including unmanned aerial vehicles and varieties of flying vehicles, as well as foreign material in the water detected by sensors **4302**, which may include chemicals. Chemicals may include, but are not limited to, oil and nuclear waste.

In one embodiment of the invention, the plurality of transient object detection sensors **4301** of the sensor system may include at least one sensor adapted to detect an item of interest. The sensor data analysis **4213**, sensor data and analysis integration **4217**, or some combination of the two may be configured to recognize, identify, and classify one or more items of interest based of data received from one or more of the transient object detection sensors **4301** of the sensor system and provide an item of interest classification signal to the vehicle control system **4218**, navigation system, hiding control system, orientation control system, stealth control system, propulsion system, maneuvering system, or buoyancy control system.

Signal processing electronics **4304** and algorithms **4305** may receive input from the sensors **4301**, **4302** and determine that an item of interest or combination of items of interest have been detected. Detection may include a determination of the location, speed, heading, velocity, and/or dimension of the object of interest. Location may include any or all of the latitude, longitude, and depth of the item of interest. Sensor **4301**, **4302** data and associated derivative information may be aggregated from each sensor **4301**, **4301** for each item of interest and may be sent over an ethernet network to computation algorithms that may detect, identify, and classify each item of interest. This kind of recognition and classification may be particularly well suited to artificial intelligence (AI) and pattern recognition algorithms. The item of interest signal and classification signal may be provided by the artificial intelligence block **4305**.

Once an item of interest has been detected, recognized, or classified that information may be sent over an ethernet network to the Mission Execution Control **4306**. The Mission Execution Control **4306** may also receive input from the Mission Plan **4303**. The Mission Execution Control **4306** may contains decision-making algorithms **4318** that may determine what hiding characteristics are desired based on the information received. Those decision-making algorithms **4318** may provide information to hiding requests **4319**, which may pass command to the Hiding Control System **4307**. The decision-making algorithms **4318** included in the Mission Execution Control **4306** may contain AI components.

The output of the Hiding Decision System may include Navigation Mode and Stealth Mode messages which are sent to the Hiding Control system **4307** over an ethernet network. The hiding control system **4307** may provide data to the propulsion system, maneuvering system, vehicle control system, or buoyancy control system, which, individually or collectively, may act to avoid physical, electrical, acoustic, or thermal detection of the unmanned vehicle by the item of interest.

FIG. **44** depicts the flow chart of the hiding control system **4307**. Data may be provided to the hiding control system **4307** from the mission execution control **4401**, which is depicted in detail in FIG. **43**.

FIG. **44** depicts how the hiding control system **4402** converts Hiding Request messages received from the mission execution control **4401** to Navigation Mode and Stealth mode control messages. Input to the hiding control system **4402** originates from the Mission Execution control **4306** depicted in FIG. **43**, which sends hiding request messages as inputs that are processed by the hiding control system **4402** and/or the stealth mode executive control **4403**.

The output of the hiding control system **4402** may be sent to the navigation mode executive control **4404**, which may provide electrical and mechanical systems to direct unmanned vehicle navigation modes. The classification signal received from the mission execution control **4401** may be provided to the hiding control system **4402**, which provides input to the navigation mode executive control **4404**, which may then use that data to provide commands used by the maneuvering system, the buoyancy system, or the propulsion system to position the unmanned vehicle in a location calculated to prevent detection of the unmanned vehicle by the item of interest.

The hiding control system **4402** may select a desired navigation mode and provide this data to the navigation

mode executive control **4404**. The navigation mode executive control **4404** may process this selection and provide messages to the specific Navigation Mode Controller **4407**, **4408**, **4409**, **4410**, **4411**, **4412**, or **4413** necessary to implement the selected navigation mode. The navigation mode executive control **4404** may also contains control logic for transitioning between selected modes of navigation. The selected navigation mode controller **4407**, **4408**, **4409**, **4410**, **4411**, **4412**, or **4413** may provide date to the navigation come control command messages **4405**, which are provided to navigation mode control **4406** to control systems of the unmanned vehicle. The navigation mode control **4406** may provide commands to the maneuvering system, buoyancy control system, or propulsion system. These systems may work independently or cooperatively to position the unmanned vehicle in a body of water at a depth lower than a depth of the item of interest and in an orientation in order to avoid detection by the item of interest.

Turning to FIG. **51**, the behavior of the vessel during different navigation modes is depicted. The vessel may be capable of operating in at least six different navigation modes, which may be referred to as surface mode **5101**, gator mode **5102**, hover mode **5103**, shark mode **5104**, porpoise mode **5105**, and diver or glider mode **5106**. The surface navigation mode control **4407** may provide navigation mode control command messages **4405** to the navigation mode control **4406** when the unmanned vehicle is in surface mode **5101**. The GATOR navigation mode control **4408** may provide navigation mode control command messages **4405** to the navigation mode control **4406** when the unmanned vehicle is in GATOR mode **5102**. The SHARK navigation mode control **4409** may provide navigation mode control command messages **4405** to the navigation mode control **4406** when the unmanned vehicle is in SHARK mode **5104**. The HOVER navigation mode control **4410** may provide navigation mode control command messages **4405** to the navigation mode control **4406** when the unmanned vehicle is in HOVER mode **5103**. The DIVER navigation mode control **4411** may provide navigation mode control command messages **4405** to the navigation mode control **4406** when the unmanned vehicle is in diver mode **5106**. The glider navigation mode control **4412** may provide navigation mode control command messages **4405** to the navigation mode control **4406** when the unmanned vehicle is in glider mode **5106**. The porpoise navigation mode control **4413** may provide navigation mode control command messages **4405** to the navigation mode control **4406** when the unmanned vehicle is in porpoise mode **5105**. Each navigation mode may include navigation and movement characteristics along six degrees of freedom, communication methods, payload control methods, and other capabilities unique to each navigation mode. The navigation modes implement the part of multi-mode behavior that applies to surface, near surface, and submarine operations.

In surface mode **5101**, the vessel may travel across the surface of a body of water. In hover mode **5103**, the vessel may move to different altitudes above or below the surface of the body of water. In GATOR mode **5102**, the vessel may be substantially submerged with a to of the vessel near or slightly above the surface of the water. In SHARK mode **5104**, the vessel may be oriented horizontally with only the bow, or a portion of the bow, of the vessel above the waterline. In porpoise mode **5105**, the vessel may move forward while alternating between a first position resting on the surface of the water and a second, completely submerged, position. In dive or glider mode **5106**, the vessel may travel similarly to porpoise mode while reaching a deeper altitude when submerged below the water line.

Returning to FIG. **44**, the output of the stealth mode executive control **4403**, which may also be referred to as a stealth control system, may be sent to a thermal cloaking system **4414**, acoustic cloaking system **4415**, radio frequency cloaking system **4416**, or radio frequency imitation system **4417**. Each of the thermal cloaking system **4414**, acoustic cloaking system **4415**, radio frequency cloaking system **4416**, and radio frequency imitation system **4417** may include electrical and/or mechanical systems to activate stealth capabilities that suppress the unmanned vehicle's detectable signatures. The stealth control system **4403** may use the classification signal to activate at least one of the thermal cloaking system **4414**, acoustic cloaking system **4415**, radio frequency cloaking system **4416**, or radio frequency imitation system **4417**. Any combination of stealth systems may be chosen. Each stealth system is independent from the other stealth systems. The thermal cloaking system **4414** may provide a control signal to a hull temperature suppression system **4418**. The acoustic cloaking system **4415** may provide a control signal to an acoustic frequency cancelling system **4419**. The radio frequency cloaking system **4416** may provide a control signal to a radio frequency suppression system **4420**. The radio frequency imitation system **4417** may provide a control signal to a frequency imitation system **4421**.

Referring to FIG. **45**, the navigation mode control is depicted. The navigation mode control command messages **4501** are received and provided to navigation control **4503** and orientation control **4504**. Navigation Control **4503** may control vessel speed and heading. Orientation control **4504** may control vessel pitch, roll, and depth. Together these may be referred to as controlling 6 degrees of freedom.

Navigation control **4503** and orientation control **4504** receive inputs from sensors **4502**. The sensors **4503** may include, but are not limited to a GPS sensor **4510**, compass **4511**, gyro sensor **4512**, pressure sensor **4513**, and water level sensor **4514**. The pressure sensor **4513** may be utilized to determine a depth of the vessel. The sensors **4502** and the environmental awareness sensors **4302** may be the same sensors. Output from the GPS sensor **4510**, Compass **4511**, and Gyro sensor **4512** may be provided to the navigation control **4503** to provide a feedback reference for speed, course and/or heading.

Output from the gyro sensor **4512**, pressure sensor **4513**, and/or water level sensor **4514** may be provided to the orientation control **4504** to provide a reference feedback for pitch, roll, depth, and water volume in the vessel.

The Navigation Control **4503** may control propulsion and steerage components **4505**. The propulsion and steerage components may include, but are not limited to, a power source, drive train, motors, propellers, engines, rudders, or vectored thrust.

The Orientation Control **4504** may include control logic that generates output to control surface actuators **4506** or a buoyancy system **4507**. The control surface actuators **4506** may control positions of trim tabs, canards, bow thrusters, or the like. The Buoyancy System **4507** may control the Ballast System **4508** and the Flotation System **4509**.

FIG. **46** provides more detail related to the orientation control **4504**. The orientation control **4603** receives Navigation Mode control command messages **4602** and controls vessel pitch, roll, yaw, and depth in response. The Orientation Control **4603** contains logic that receives requests for particular orientation parameters and provides control commands in response to those requests. The orientation param-

eters may include pitch, roll, yaw, and depth. To achieve requested pitch and roll orientation parameters, the orientation control **4603** may send control commands to control surface actuators **4618** and the Buoyancy Control system **4604**. The division of responsibilities between the control surface actuators **4618** and the buoyancy control system **4604** may be dependent upon the Navigation Mode. The control surface actuators **4618** may provide signals to one or more of the trim tabs, canards, and bow thrusters **4619** to achieve the desired pitch and roll. In one embodiment, the trim tabs may be positioned in the aft of the vessel and the canards may be positioned in the bow of the vessel.

Vessel control surfaces, including, but not limited to, trim tabs, canards, and bow thrusters **4619**, may be moved by electrically controlled actuators **4618** that receive signals from the Orientation Control **4603** module. Power may supplied by the energy source, which may be one or more batteries, and the conversion from digital signals to motive power may occur in circuitry that exists in the on-board processor or within the actuators **4618** themselves.

The Orientation Control module may receive inputs from sensors **4601**. The sensors **4601** may include, but are not limited to, a gyro sensor **4612**, pressure sensors **4613**, **4616**, **4617**, environmental sensors **4614**, and water level sensors **4615**. The gyro sensor **4612** may be a 3-axis accelerometer. The environment sensors **4614** may detect sea state, as defined by wave motion, wind speed, wind direction, current speed, or current direction. The pressure sensors **4613**, **4616**, **4617** may be utilized to detect different data. At least one depth pressure sensor **4613** may detect a depth of the vessel. A water pressure sensor **4616** may detect a water pressure. An air pressure sensor **4617** may detect an air pressure.

The Buoyancy Control system **4604** may receive command and data messages from the Orientation Control **4603**. These messages may contain requests for orientation parameters related to depth, pitch, or roll. These messages may also contain sensor **4601** data including information related to pitch, roll, yaw, and depth. These messages may be processed by the buoyancy control system **4604** and translated to instructions to the Ballast Control system **4605** or the floatation control system **4609**.

The ballast control system **4605** may control the volume of water in the vessel and direct the systems necessary to remove water from or add water to the vessel to achieve a desired volume of water. Specifically, water may be carried in ballast containers **4608** or the hull. The Ballast Control System **4605** receives an input from water level sensors **4615** inside the vessel and water pressure sensors **4616** indicating pressure in ballast containers **4608**. From this sensor data, the volume of water in the vessel or ballast containers **4608** may be determined and compared to the desired water volume as directed from the buoyancy control system **4604**. Water volume may be adjusted by activating water pumps or valves **4606** to pump water into the ballast containers **4608** from the ambient water environment **4607** or to pump water out of the ballast containers **4608** into the ambient water environment **4607** until the water volume in the ballast containers **4608** matches the requested water volume. The ballast control system **4605** may convert digital signals to electrical output that drives actuators **4606** that pump the water.

The flotation control system **4609** may control the volume of air in the vessel and direct the systems necessary to remove air from or add air to the vessel to achieve the desired volume of air. Specifically, air may be carried in pneumatic flotation bladders **4611**. The Flotation Control System **4609** may receive input from air pressure sensors **4617** measuring air pressure in pneumatic flotation bladders **4611**. From this sensor data, the volume of air in a plurality of air bladders **4611** may be determined and compared to the desired volume of air as directed from the buoyancy control system **4604**. Air volume may be adjusted by activating an actuator or valve **4610** to pump air into the pneumatic flotation bladders **4611** or to release air from the pneumatic flotation bladders **4611** until the volume of air in the air bladders **4611** matches the requested volume of air. The flotation control system **4609** may convert digital signals to electrical output that drive actuators **4610** that pump the air.

As described, the Buoyancy Control system **4604** may control two systems simultaneously to achieve accurate control of total buoyancy and center of buoyancy of the vessel which may enable multiple orientations, which are grouped as Navigation Modes described in FIG. **51**.

FIG. **47** depicts the stealth mode executive control **4701**. The Stealth control system **4702** may receive Stealth Mode command messages, as depicted in FIG. **44**. In response to the stealth mode command messages, a plurality of vessel signatures including thermal, acoustic or radio frequencies may be suppressed. Further, the stealth control system **4702** may enable the vessel to emit a signal that imitates a different kind of vessel or maritime object. The Stealth control system **4702** may activate any combination of stealth systems. The stealth systems may include a thermal cloaking system **4703**, an acoustic cloaking system **4704**, a radio frequency cloaking system **4705**, and a radio frequency imitation system **4706**.

The thermal cloaking system **4708** may provide a control signal to a hull temperature suppression system **4703**. The thermal cloaking system **4708** may be adapted to decrease a temperature of the unmanned vehicle's body by activating the hull temperature suppression system **4703**.

The thermal cloaking system controller **4708** may receive a message from the Stealth Control system **4702** with instructions to maintain, or limit, the maximum hull temperature to within a specified difference of the ambient water temperature. The thermal cloaking system controller **4708** may also receive a message from the stealth control system indication what Navigation Mode or Hull Spray action to take to reduce the hull temperature.

The thermal cloaking system controller **4708** may receive data from temperature sensors **4707** to determine the current hull temperature and the ambient water temperature. A hull temperature sensor **4713** may be positioned to measure and provide data related to the maximum hull temperature and an ambient water temperature sensor **4714** may be positioned to measure and provide data related to the ambient water temperature. If the difference between the ambient water temperature and the hull temperature is above the specified difference, the thermal cloaking system controller **4708** may provide a control signal to the navigation mode control **4710** to enter a navigation mode calculated to reduce the hull temperature. The navigation mode control **4710** may be a part of the vehicle control system and may control the propulsion system, maneuvering system, vehicle control system, or buoyancy control system to maintain an actual difference between the hull temperature and the ambient temperature less than the target threshold when the thermal cloaking system **4703** is activated.

Similarly, if the difference between the ambient water temperature and the hull temperature is above the specified difference, the thermal cloaking system controller **4708** may provide a control signal to the hull spray actuator **4709** to activate the hull spray pump **4711** and control the hull spray plumbing and nozzles **4712** to spray the hull with ambient

water to reduce the hull temperature. The hull spray actuator **4709** may be a part of the vehicle control system and the hull spray pump **4711** and hull spray plumbing and nozzles **4712** may be a part of a water spray system. Water output from the water spray system may be directed at the exposed hull surface to maintain an actual difference between the hull temperature and the ambient temperature less than the target threshold when the thermal cloaking system **4703** is activated.

For example, if the maximum hull temperature exceeds the specified temperature threshold, the vessel may be instructed to go into PORPOISE mode until the hull decreases temperature. By way of another example, if the maximum hull temperature exceeds the specified temperature threshold, the hull spray mechanism may be activated.

The acoustic cloaking system **4704** may be adapted to cancel an acoustic frequency emitted by the unmanned vehicle. The Acoustic Frequency Controller **4717** may receive a message from the Stealth Control system **4702** with instructions to suppress the acoustic signature of the vessel. The controller **4717** may receive input from an acoustic sensor **4715**. By way of example, and not as a limitation, the acoustic sensor **4715** may be a microphone or other sensor adapted to sense a detectable frequency. An algorithm may receive data detected by the acoustic sensor **4715** or control data from the frequency controller **4714** and be configured to control a frequency generator **4716** to output a cancelling frequency calculated to suppress the detectable frequency sensed by the acoustic sensor **4715**. The cancelling frequency may suppress or cancel the frequencies sensed by the acoustic sensor **4715**. The cancellation frequency may be sent to a frequency generator **4716** in the form of an electrical or digital signal.

The radio frequency imitation system **4706** may be adapted to recreate a target radio frequency. The radio frequency imitation system **4706** may receive a message from the Stealth Control system **4702** with instructions to imitate a known maritime vessel or other object. The object to be imitated could be man-made or natural. The imitation controller **4721** may contain a library of maritime vessel and object frequencies that are matched to the requested object and the matching frequencies may sent to a frequency generator **4722** in the form of an electrical or digital signal or controls may be provided to the frequency generator **4722** to cause the frequency generator to output the desired frequency. The frequency library may include a designation of a plurality of maritime vessels and objects, which may be referred to collectively as frequency generators, and their associated output frequencies. The frequency generator **4722** may be configured to output a frequency associated with one or the plurality of frequency generators contained in the library.

The radio frequency cloaking system **4705** may be adapted to alter the radio frequency emitted by the vessel. The Radio Frequency Suppression Controller **4718** may receive a message from the Stealth Control system **4702** with instructions for which communication frequencies to suppress. These messages may be translated and sent to an Emission Controller **4719** which has logic to determine what frequencies to suppress and the nature of the suppression from turning off those frequencies, choosing other selective frequencies or changing the bandwidth and period of communications. These parameters may be converted to instructions and sent to the vessel's communication modules **4720**. The radio frequency cloaking system **4705** may be adapted to alter the emitted radio frequency of the Bessel by at least one of: suppressing an emission of the radio frequency, changing a bandwidth of the radio frequency, and changing a duration of transmission of the radio frequency.

Referring to FIGS. **48***a-c*, schematic diagrams illustrating the layout of the physical components of the buoyancy control system are presented. The buoyancy control system includes the ballast system and the flotation system. The ballast system controls water volume within the vessel hull. The flotation system controls the air volume within the vessel hull. These two systems work together and are coordinated by the Orientation Control System described above. The ballast system primarily controls the total buoyancy of the vessel, which changes its depth, while the flotation system is primarily used to control the center of buoyancy, which changes pitch and roll of the vessel.

The Ballast subsystem contains the following components as shown in FIGS. **48***a-c*:

an electronically controller diverter valve **4809** that controls water flow from external ports on the top and bottom of the vessel to,

an electronically controlled bi-directional positive displacement pump **4806** that pumps water in or out of the vessel through plumbing lines connected to ports in the bottom of the vessel and whose flow is controlled by,

electronically actuated valves **4807**, **4808** with ports directing water into or our of the bottom of the hull.

Four water level sensors **4811**, **4812**, **4813**, **4814** are located inside the vessel, two near the top to indicate that water has filled the vessel and two on the bottom, one in each sponson, to indicate that water is evacuated from the vessel.

The central processing control unit **4815** may contains a computer or other computing device for logic processing and input and output conversions between digital signals and electronic signals that are used to actuate valves and pumps in the ballast control system.

The flotation control system includes an air distribution controller **4805**. The air distribution controller **4805** controls the volume of air in air bladders **4801**, **4802**, **4803**, **4804** by pumping air in or out through air lines. The volume of air is individually controlled in each air bladder and the air bladders are distributed in four quadrants within the vessel, port, starboard, bow, aft. This may enable control to move the center of buoyancy backward and forward, and left and right, which translates to pitch and roll. The central processing control unit **4815** may send actuation signals to the air distribution controller as described in FIG. **49**. The flotation control system may also include a pressure sensor **4810**.

Turning to FIG. **49** a schematic diagram illustrating the physical components of the air distribution controller used to control the volume of air in each of the air bladders **4914**, **4913**, **4919**, **4920** is shown. The air bladders **4914**, **4913**, **4919**, **4920** distributed in the vessel allow for controlling the center of buoyancy. The air distribution controller **4915** includes an air distribution manifold **4916**, an air pump **4917**, and a high-pressure air reservoir **4918**. The air distribution manifold **4916** may contain a set of air channels that direct air between the air bladders **4914**, **4913**, **4919**, **4920** and either ambient air **4912** or air from the high-pressure reservoir **4918**. Air channels may contain electronically activated valves **4901**, **4902**, **4903**, **4904**, **4905**, **4906** that are controlled from the central processing control unit **4922**. The combination of valves in open or closed positions enable distribution of air between any combination of bladders **4913**, **4914**, **4919**, **4920** and one of the two air sources **4912**, **4918**. Signals from air pressure sensors **4907**, **4908**, **4909**, **4910**, **4911** are transmitted to the central processing unit **4922**, which may use algorithms to determine the volume of

air in each bladder **4913**, **4914**, **4919**, **4920**. The air distribution controller may receive electrical power from one or more batteries **4921**.

Turning to FIGS. **50***a-b* schematic diagrams illustrating the layout of thermal signature suppression components are depicted. Thermal signature suppression logic may be processed in the **5015** central processing unit. Temperature sensors **5001**, **5002** may be placed to read exterior hull temperature at locations expected to be the highest temperatures. A temperature sensor **5003** may be placed to read ambient water temperature. The temperature sensor signals may be routed to the central processing unit **5015**. When hull cooling is required, the embodiment of FIGS. **50***a-b* depicts a water spray system to suppress the thermal signature. When thermal suppression is called for, the central processing unit **5015** may direct the external bottom water port to be opened by opening the diverter valve **5009**, actuating the water pump **5006**, and opening the internal water valve **5007**, which results in water flow to spray nozzles **5004**, **5005**. When the hull temperature is cooled sufficiently, the process may be reversed. The valves may be closed and the water pump may be turned off.

As described above, hull temperature suppression may be achieved by employing a navigation mode the washes the hull and in this case, the spray system may not be used.

Many modifications and other embodiments of the invention will come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is understood that the invention is not to be limited to the specific embodiments disclosed, and that modifications and embodiments are intended to be included within the scope of the appended claims.

The claims in the instant application are different than those of the parent application or other related applications. Applicant therefore rescinds any disclaimer of claim scope made in the parent application or any predecessor application in relation to the instant application. Any such previous disclaimer and the cited references that it was made to avoid, may need to be revisited. Further, any disclaimer made in the instant application should not be read into or against the parent application.

What is claimed is:

1. An unmanned vehicle comprising:

a vehicle body comprising a pair of substantially parallel sponsons;

a propulsion system carried by the vehicle body;

a maneuvering system carried by the vehicle body;

a vehicle control system carried by the vehicle body to control a speed, an orientation, and a direction of travel of the unmanned vehicle in combination with the propulsion system and the maneuvering system;

a rack carried by the vehicle body comprising a retractable mount configured to move between a down position and an up position;

a sensor system carried by the rack and comprising a plurality of transient object detection sensors to sense transient objects in an environment of unmanned vehicle; and

a power supply carried by the vehicle body;

wherein the plurality of transient object detection sensors of the sensor system at least include a sensor adapted to detect an item of interest and provide an item of interest signal to the vehicle control system;

wherein the vehicle control system is adapted to receive the item of interest signal, identify an item of interest classification and provide a classification signal;

wherein the classification signal is determined by the item of interest classification and is utilized by the propulsion system, maneuvering system, vehicle control system, or retractable mount to avoid physical, electrical, acoustic, or thermal detection of the unmanned vehicle by the item of interest.

2. The system of claim **1** wherein at least one of the maneuvering system and the propulsion system is used to position the unmanned vehicle in a location calculated to prevent detection of the unmanned vehicle by the item of interest.

3. The system of claim **1** wherein the plurality of transient object detection sensors are selected from the group including an electro-optical sensor, an infrared sensor, a radar sensor, a lidar sensor, an acoustic sensor, and a sonar sensor.

4. The system of claim **1** wherein the plurality of transient object detection sensors further includes at least one other sensor to determine at least one of a location of the item of interest, a velocity of the item of interest, and a dimension of the item of interest.

5. The system of claim **1** wherein the down position of the retractable mount is defined as the rack being positioned abuttingly adjacent to the vehicle body, and wherein the up position of the retractable mount is defined as the retractable mount being substantially latitudinally extended from the vehicle body.

6. The system of claim **1** wherein the item of interest classification is selected from the group consisting of an aquatic vessel, a human, a mine, an aerial vehicle, and a chemical.

7. The system of claim **1** further comprising:

a stealth control system;

a thermal cloaking system;

an acoustic cloaking system;

a radio frequency cloaking system; and

a radio frequency imitation system;

wherein the classification signal is utilized by the stealth control system to activate at least one of the thermal cloaking system, the acoustic cloaking system, the radio frequency cloaking system, and the radio frequency imitation system.

8. The system of claim **7** wherein the thermal cloaking system is adapted to decrease a temperature of the vehicle body.

9. The system of claim **8** wherein the thermal cloaking system comprises:

a first temperature sensor positioned to measure a hull temperature; and

a second temperature sensor positioned to measure an ambient temperature;

wherein a target threshold difference between the hull temperature and the ambient temperature is determined; and

wherein the vehicle control system controls the propulsion system, maneuvering system, or the vehicle control system to maintain an actual difference between the hull temperature and the ambient temperature less than the target threshold when the thermal cloaking system is activated.

10. The system of claim **8** wherein the thermal cloaking system comprises:

a first temperature sensor positioned to measure a hull temperature; and

a second temperature sensor positioned to measure an ambient temperature;

wherein a target threshold difference between the hull temperature and the ambient temperature is determined; and

wherein the vehicle control system controls a water spray system directed at the exposed hull surface to maintain an actual difference between the hull temperature and the ambient temperature less than the target threshold when the thermal cloaking system is activated.

11. The system of claim **7** wherein the acoustic cloaking system is adapted to cancel an acoustic frequency emitted by the unmanned vehicle.

12. The system of claim **11** wherein the acoustic cloaking system comprises:

an acoustic sensor adapted to sense a detectable frequency; and

a frequency generator configured to output a canceling frequency calculated to suppress the detectable frequency.

13. The system of claim **7** wherein the radio frequency cloaking system is adapted to alter a radio frequency emitted by the unmanned vehicle.

14. The system of claim **13** wherein the radio frequency cloaking system is adapted to alter the emitted radio frequency by at least one of: suppressing an emission of the radio frequency, changing a bandwidth of the radio frequency, and changing a duration of transmission of the radio frequency.

15. The system of claim **7** wherein the radio frequency imitation system is adapted to recreate a target radio frequency.

16. The system of claim **15** wherein the radio frequency imitation system comprises:

a frequency library including a designation of a plurality of frequency generators and associated frequencies; and

a frequency generator configured to output a frequency associated with one of the plurality of frequency generators.

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